Winter Water Quality In The Athabasca River System 1988 and 1989

Alberta
ENVIRONMENT

WINTER WATER QUALITY IN THE ATHABASCA RIVER SYSTEM

1988 and 1989

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Edmonton, Alberta
August 1989

EXECUTIVE SUMMARY

In response to the rapid expansion in the pulp mill industry and the concern about winter water quality in the Athabasca River, five water quality surveys were carried out in January to March of 1988 and 1989. This report presents and interprets the data, compares them to previous data, assesses effluent impact, and evaluates compliance with the Alberta Surface Water Quality Objectives (ASWQO) and the Canadian Water Quality Guidelines (CWQG).

Effluents to the Athabasca River were the Hinton pulp mill and municipal effluent (HCE), the Millar Western Pulp Ltd. (MWPL) effluent (1989 only), treated municipal sewage from Whitecourt, Athabasca and Ft. McMurray, and the Suncor Oil Sands process effluent. In both years, river flows during the surveys were about 70% of mean winter flow but were greater than the 1 in 10 year low flow. Effluent impact is generally greatest in winter due to the low flow and low dilution capacity in the river. Low winter flows persist for three to four months of the year.

During winter, the Athabasca flows from the mountains in an alkaline, hardwater, clear, base flow condition. As it progresses northeast across the province through the boreal forest, it receives natural tributary inflow, which tends to alter its major ion composition and increase its organic carbon, colour, iron and manganese concentrations.

The pulp mill effluents had adverse effects on concentrations of dissolved oxygen, phenolic compounds, trace organic compounds, colour, odour, phosphorus, and manganese in the Athabasca River. This resulted in non-compliance with the ASWQO and/or the CWQG for oxygen, phenols, colour, odour and phosphorus. Heat in the effluent created an ice-free reach downstream of each mill. In addition, the pulp mill effluents increased river concentrations of sodium, chloride, sulphate, sulphide, suspended solids, tannin and lignin, organic carbon, nitrogen, and bacteria, and they discharged a high load of zinc. These findings are consistent with assessments carried out previously with regard to the HCE and with regard to the bleached kraft pulp mill on the Wapiti-Smoky River system.

The municipal sewage effluents caused small to moderate increases in nitrogen, phosphorus, and bacteria in the Athabasca River. No effect of the Suncor Oil Sands effluent on river water quality was discernible. Concentrations of calcium, magnesium, bicarbonate, alkalinity, hardness, pH, fluoride, and most metals were not adversely affected by effluent discharges.

ACKNOWLEDGEMENTS

Water quality sampling in 1989 was carried out by D. Allan, D. LeClair, B. Jackson, J. Willis, C. Rickard and B. Lange of the EQMB. Most of the sampling in 1988 was done by D. Fernet and C. Bjornson of Environmental Management Associates. Helicopter support for much of the sampling was provided by Alberta Public Works, Supply and Services. Effluent sampling was done by G. Scammell (Standards and Approvals Division); streamflow measurements were obtained by G. Coles, N. Assmus, D. Rennie, S. Flett and crews (Technical Services Division), and by Water Survey of Canada. Samples were analyzed at the Alberta Environmental Centre (under the supervision of F. Dieken and D. Smillie), at Chemex Labs Alberta Ltd. (D. Laberge), at the Alberta Provincial Laboratory of Public Health, at the Millwoods facility of the EQMB (M. McCutcheon) and at Enviro-Test Laboratories, Edmonton (E. Erickson).

Electronic data processing and computer graphics were carried out by D. Asquin, R. Tchir and M. Soetaert of the EQMB. R. Bothe (Technical Services Division) prepared hydrographs; G. Scammell, I. Mackenzie, and A. Pentney (Standards and Approvals Division) supplied effluent information.

Comments on the draft report were provided by J.B. Kemper, A. Pentney, I. Mackenzie, P. Chow-Fraser, J. Shaw, J. Snidal, D. Smillie, and R. Bothe. The report was typed by L. Smith.

ABBREVIATIONS

d/s	Downstream
u/s	Upstream
AEC	Alberta Environmental Centre
AOSERP	Alberta Oil Sands Environmental Research Program
AR	Athabasca River
ASWQO	Alberta Surface Water Quality Objectives
BKME	Bleached Kraft Mill Effluent
BOD	Biochemical oxygen demand
CCREM	Canadian Council of Resources and Environmental Ministers
COD	Chemical oxygen demand
CTMP	Chemi-Thermomechanical Pulp
CV	Coefficient of Variation
CWQG	Canadian Water Quality Guidelines
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DTPA	Diethylenetriaminepentaacetic acid
EDTA	Ethylenediaminetetraacetic acid
EMA	Environmental Management Associates
EQMB	Environmental Quality Monitoring Branch
ETL	Enviro-Test Laboratories
GCDWQ	Guidelines for Canadian Drinking Water Quality
HCE	Hinton combined effluent
MWPL	Millar Western Pulp Ltd.
MWPLE	Millar Western Pulp Ltd. Effluent
SOD	Sediment oxygen demand
SPC	Standard plate count (heterotrophic bacteria)
STP	Sewage treatment plant
SS	Suspended solids
T&L	Tannin and lignin
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TP	Total phosphorus
USEPA	United States Environmental Protection Agency

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1. INTRODUCTION

The Athabasca River originates in the mountains of Jasper National Park and flows in a northeasterly direction for some 1400 km to Lake Athabasca. The river's basin extends from the Rocky Mountains through foothills, boreal forest and agricultural land, to the Canadian Shield in the northeast. Factors in the basin that are relevant to Athabasca River water quality include the headwater inflow, inflows from several sizeable tributaries, and effluents from two pulp mills, one oil sands plant, and several municipalities (Hamilton et al., 1985).

Previous water quality investigations on the Athabasca River include long-term monitoring of trends (Environmental Quality Monitoring Branch -EQMB-, Alberta Environment, unpublished data), surveys under the Alberta Oil Sands Environmental Research Program (AOSERP; Corkum, 1985), baseline data collection for river basin planning (Hamilton et al., 1985), and the assessment of effects from existing effluents (EQMB, unpublished data).

The pulp mill industry in the Athabasca River basin is expanding rapidly, and the oil sands industry may expand as well. Pulp mills generate relatively large volumes of wastewater which pose potential impacts for water quality. The capacity of a river to dilute effluent is directly related to its discharge, and discharge in the Athabasca River is lowest in winter. Thus, for some compounds the potential impact of effluents on Athabasca River water quality would be greatest during winter. In addition, ice cover greatly restricts re-aeration of river water during winter. Re-aeration replenishes dissolved oxygen that is consumed by oxygen demanding material present naturally and in effluent discharges.

In view of the rapid expansion of the pulp mill industry and the concern about winter water quality in the Athabasca River, two water quality surveys were carried out in 1988, from February to March, and three surveys were carried out in 1989, from January to March. The objectives of these surveys were to obtain additional data that could be used:

- for water quality protection planning,
- to define a baseline for present winter water quality conditions, and
- to better assess the impacts of existing effluents on river water quality.

This report presents and interprets the findings of the 1988 and 1989 winter water quality surveys.

2. METHODS

2.1 General

Five water quality surveys were carried out on the Athabasca River system during 1988 and 1989:

Survey 88-1: 1-11 February 1988; Hinton to Town of Athabasca

Survey 88-2: 4-9 March 1988; Hinton to Town of Athabasca

Survey 89-1: 9 January - 15 February, 1989; Hinton to Lake Athabasca

Survey 89-2: 26 January - 6 February, 1989; Whitecourt to Town of Athabasca

Survey 89-3: 13 February - 16 March, 1989; Hinton to Lake Athabasca

In addition, a separate program was carried out on the reach between Ft. McMurray and Lake Athabasca during 1987 to 1988. Relevant data from that work (January and March, 1988) are included in this report. To simplify the presentation of results, data collected 19 to 20 January 1988 from the reach between Ft. McMurray to Lake Athabasca are included in Survey 88-1, and data collected 15 to 17 March 1988 are included in Survey 88-2. Oxygen concentrations were also measured with continuous, recording monitors at selected sites during January to March, 1989; these data are included in this report. Surveys 88-1 and 88-2 were carried out by Environmental Management Associates (EMA), under contract to Alberta Environment.

In the Athabasca River basin, water samples were collected from the mainstem, tributaries and effluents (Figure 1; Table 1). Samples were collected in a downstream direction, starting at Hinton and ending at Lake Athabasca. The date and time that samples were collected

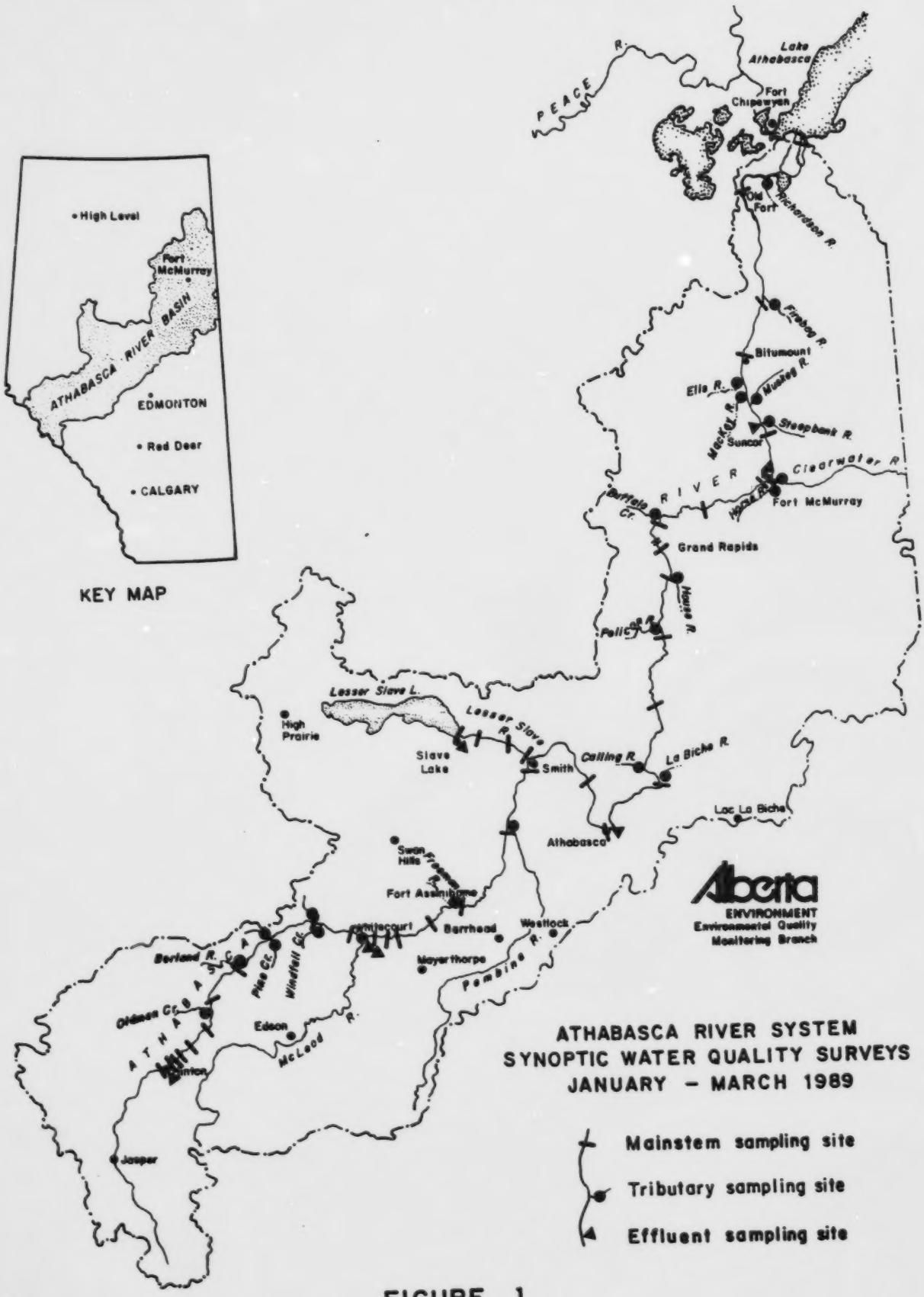

High Level
Fort McMurray
ATHABASCA RIVER BASIN
EDMONTON
Red Deer
CALGARY
KEY MAP
PEACE R.
Lake Athabasca
Fort Chipewyan
Old Fort
Richardson R.
Firebag R.
Bitumount
Ells R.
Muskeg R.
Steepbank R.
Suncor
Clearwater R.
Horse R.
Fort McMurray
Buffalo Cr.
RIVER
Grand Rapids
House R.
Pelican
Lesser Slave L.
Lesser Slave R.
High Prairie
Slave Lake
Smith
Calling R.
La Biche R.
Loc La Biche
Athabasca
Swan Hills
Fort Assiniboine
Whitecourt
Barrhead
Westlock
Berland R.
Pine Cr.
Windfall Cr.
Meyerthorpe
Pembina R.
Oldman Cr.
ATHABASCA
Edson
McLeod R.
Jasper
Alberta
ENVIRONMENT
Environmental Quality
Monitoring Branch
ATHABASCA RIVER SYSTEM
SYNOPTIC WATER QUALITY SURVEYS
JANUARY - MARCH 1989
Mainstem sampling site
Tributary sampling site
Effluent sampling site

FIGURE 1

TABLE 1. Sampling sites in the Athabasca River system, January to March 1989.

Description	Station Code 00AL07-	River km
AR u/s Hinton	AD1085	1243.4
Hinton Combined Effluent	20AL07AD1000;-1	1241.5
AR 1 km d/s HCE	AD1180	1240.4
AR 6 km d/s HCE	Left AD1200; Right AD1220, Comp. AD1225	1235.9
AR 11 km d/s HCE	AD1280	1230.5
AR 21 km d/s HCE	AD1380	1220.5
AR 36 km d/s HCE	AD1565	1204.8
Oldman Creek	AD1700	1187.7
AR 60 km d/s HCE	AD1765	1181.2
Spring 1	AD2001	1165.0
AR u/s Berland R.	AD2060	1139.6
Berland River	AC1000	1139.2
AR d/s Berland R.	AE0800	1138.4
Spring 2	AE0501	1124.4
Marsh Head Creek	AE0900	1111.7
Pine Creek	AE1050	1111.5
Spring 3	AE1141	1093.7
Two Creek	AE1230	1084.5
AR 1.5 km d/s Two Cr.	AE1260	1082.9
Windfall Creek	AE1290	1076.5
AR at Windfall Bridge	AE1350	1066.3
AR u/s Whitecourt	AE1495	1033.6
McLeod River	AG2060	1032.4
Millar Western Effluent	20AL07AH1000;-1	1031.9
AR 3 km d/s McLeod R.	AH0660	1029.4
Whitecourt STP (grab)	21AL07AH0200	1028.5
AR 10 km d/s McLeod R.	AH1044	1022.3
AR at Blue Ridge Br.	AH1085	1007.2
AR d/s Five Mile Is.	AH1150	969.0
AR at Ft. Assin. u/s Freeman R.	AH1310	937.6
Freeman River	AH2000	937.4
AR u/s Pembina R.	BD0500	850.0
Pembina R.	BC0990	849.6
AR u/s Smith, @ Hwy 2	BD1000	805.9
Lesser Slave R.		794.0
- at Lake outflow	BK2100	71.5
- Slave Lake STP (grab)	21AL07BK5000	68.3
- at Mitsue Bridge	BK2110	53.5
- u/s Driftwood R.	BK2130	25.5
- near AR confluence	BK2150	0.5
AR north of Howie L.	BE2200	732.3
AR at Town of Athabasca	BE2320	687.0
Town of Athabasca STP (grab)	21AL07CB0100	686.0
AR u/s La Biche R.	CB2410	626.0
La Biche R.	CA1500	625.6
Calling R.	CB2500	610.1
AR near McMillan L.	CB3300	565.5
AR u/s Pelican R.	CB3800	503.0
Pelican R.	CB3900	501.3
AR u/s House R.	CB4150	443.5
House R.	CB4500	443.0
AR u/s Grand Rapids	CC2050	435.8
AR u/s Buffalo Cr.	CC3050	398.5
Buffalo Creek	CC4000	397.9
AR u/s Boiler Rapids	CC4050	355.9
AR u/s Horse R.	CC0600	297.6
Horse River	CC0750	296.1
Clearwater River	CD1200	292.8
Ft. McMurray STP (grab)	21AL07DA1000	292.9
AR u/s Suncor	DA0985	265.2
Suncor Process Effl.(grab)	20AL07DA1000	262.4
Steepbank River	DA1200	260.3
Muskeg River	DA2650	244.5
Mackay River	DB1050	240.6
Ells River	DA3350	223.2
AR near Bitumount	DA4250	214.4
AR u/s Firebag R.	DA5050	171.4
Firebag River	DC0900	167.7
AR at Old Fort	DD0900	86.6
Richardson River	DD1140	55.2
AR - Big Point Channel Mouth	DD1800	4.7
AR - Goose Island Channel Mouth	DD1700	

River km from Alberta Research Council maps. Tributaries are measured to the centre of the mouth. AR Athabasca River. d/s downstream. u/s upstream

corresponded to the estimated time of travel for a "parcel" of water flowing down river. A comprehensive group of water quality constituents was measured; particular emphasis was placed on those constituents relevant to pulp mill effluents. The specific sites and constituents sampled different from survey to survey; details are included in Appendices 1 to 6.

2.2 Field

River samples were generally collected from holes drilled through the ice in the centre of the river channel. In 1988, samples were also collected near the left and right banks of the channel. Access for much of the sampling was by helicopter. Effluents were sampled as close to their point of discharge to the river as possible. Tributaries were sampled near their confluence with the Athabasca, except that four additional sites were sampled along the Lesser Slave River (Table 1). The most comprehensive survey was 89-3, when 35 mainstem, 29 tributary, and 7 effluent sites were sampled.

At river sites, grab samples were collected from below the ice surface, either directly into the sample bottle or via an intermediate collecting vessel, as appropriate. Sample bottles were triple-rinsed with sample water at each site, except for trace organic and bacteria bottles. The collecting vessel was acid-washed daily. Samples for Winkler oxygen analysis were collected in replicate with a displacement-type APHA sampler (Greenberg et al., 1985). Temperature, pH, oxygen, and conductance were measured in situ with field meters. Any odour of the water was described by the field sampling crew as to nature and intensity, either directly from the cleaned and flushed auger hole or from a fresh sample in a glass container.

Grab samples and time-integrated, 24-hour composite samples were collected from pulp mill effluents. Grab samples were collected from all other effluents. Effluent sampling equipment was kept separate from river sampling equipment.

Blind replicate and field blank samples were collected periodically for quality assurance. The replicates were serial grab samples collected at the same site and submitted blind to the lab. The blank samples contained distilled water from the analytical lab; the water was taken into the field and used to fill regular sample bottles under typical sampling conditions.

Samples were collected in appropriate containers, fixed with proper preservatives, and kept dark and cool (but not frozen) until they were analyzed (Appendix 7). Samples for Winkler oxygen analysis were fixed on site with manganous sulphate and alkali-iodide-azide reagents. Samples for analysis of chlorophyll-a and the dissolved fractions of phosphorus, nitrogen, and BOD were filtered at the end of the day in which they were collected. Samples normally reached the lab by the morning after collection.

Dissolved oxygen concentrations were also measured with continuously recording, submersible meters (Hydrolab Corp., Data Sonde Model 2030). The meters were installed under the ice at or near the centre of the channel near the Windfall bridge, the Highway #2 bridge upstream of Smith, and the Town of Athabasca bridge. They were also installed in the water intakes of the Hinton and Ft. McMurray pumphouses; these intakes draw water from the main channel of the Athabasca River. These meters were operational for much of January through March, 1989.

Additional sites along the mainstem and at tributary mouths were monitored occasionally during that time period. The Data Sondes were left in situ for periods up to two weeks. Samples for Winkler oxygen analysis were collected when the meters were installed and retrieved.

Discharge of the Athabasca River and selected tributaries was measured by Technical Services Division (Alberta Environment) or Water Survey of Canada. Discharge of the effluents was obtained from company or municipal records.

2.3 Laboratory

The methods used to analyze the water quality parameters are given in Appendix 7. Particular care was taken to analyze oxygen and nitrogen species and to initiate the analysis of biochemical oxygen demand (BOD) within 24 hours of the time samples were collected. Oxygen was analyzed with the azide-Winkler method at the field base or at the Mill Woods (Edmonton) facility of the Environmental Quality Monitoring Branch (EQMB); the sodium-thiosulphate titrant was standardized regularly. Nitrogen, BOD, and bacterial parameters were analyzed in both years by Chemex Labs Alberta Ltd., Calgary. River samples for BOD analysis were not diluted; effluent samples were run at a range of dilutions, depending on the anticipated BOD. Samples for BOD analysis were generally not seeded.

Chemex analyzed most parameters for surveys 88-1 and 88-2, and analyzed diethylenetriaminepentaacetic acid (DTPA) and ethylenediaminetetraacetic acid (EDTA) in 1989. In 1989, most parameters were analyzed by the Alberta Environmental Centre (AEC), Vegreville. In both years of the study, trace organic compounds in river samples were

analyzed by AEC. Trace organics in pulp mill effluents were analyzed by AEC in 1988 and by Enviro-Test Laboratories (ETL), Edmonton in 1989. For survey 89-3, samples from two river sites were also analyzed for trace organics by ETL.

For trace organics, primary emphasis was placed on the non-pesticide "priority pollutants". These consist of 90 organic contaminants of highest priority in aquatic systems, as identified by the U.S. Environmental Protection Agency (USEPA, 1986; Keith and Telliard, 1979; Appendix 8). In addition to the priority pollutants, a number of other extractable (semi-volatile) trace organic compounds were also analyzed (Appendix 9).

2.4 Data Treatment and Interpretation

All data were inspected by the sampler and the project manager; questionable values were checked with lab and/or field personnel. Questionable values were only discarded if a reason for the aberration could be identified. If oxygen values from the Data Sondes differed by more than 0.5 mg/L from the paired Winkler measurement, oxygen data from the Data Sondes, for that period, were discarded. After inspection and verification, lab data were transferred electronically to the NAQUADAT computer data base of EQMB. To avoid re-entry errors, the data were downloaded electronically from NAQUADAT to an IBM-AT personal computer for manipulation and for presentation in Appendices 1 to 5.

Statistical analyses were carried out with Statgraphics statistical software (Statistical Graphics Corporation). All statistical tests are described by Sokal and Rohlf (1981). Data were tested for a normal distribution (Kolmogorov-Smirnov Test); and if necessary, data were transformed prior to analysis with parametric statistical tests.

For many of the water quality constituents discussed subsequently, figures are included that (1) illustrate concentrations of the constituents along the length of the river, (2) include historical data for comparison, and (3) indicate an appropriate water quality objective or guideline if available. To reduce clutter, data from only two to four of the surveys, usually the more detailed ones, are included in each figure.

On each figure, historic winter data are summarized for up to six sites along the river. These data were compiled from NAQUADAT for the stations listed in Appendix 10, for the months of January to March. All historic data were collected after the Hinton pulp mill commenced operations in 1957. These data were edited to include only those values that were determined with similar analytical methods to the ones used in this study.

Mass loads of constituents were calculated for selected sites and effluents in order to determine whether loading from the effluents and/or tributaries could account for observed changes in water quality in the Athabasca River. River discharge was not measured at all sites where loads were calculated. In such cases, discharge was estimated from the flow at the nearest gauged site, corrected for intervening tributaries.

The calculated loads are estimates and are subject to a number of factors which affect their accuracy and their use in comparing upstream and downstream loads:

- incomplete mixing at a site affects accuracy of grab samples,
- inflow of small tributaries and groundwater was ignored,

- single grab samples may not accurately describe water quality,
- concentrations below detection limits were assumed to be one-half the detection limit,
- the sampling progression did not always match the river's mean time of travel, and
- constituents may change in concentration from site to site because of in-river physical, chemical, and biological processes.

Nonetheless, the load estimates are sufficiently accurate to aid in interpreting river water quality.

2.5 Compliance

River water quality was assessed by comparing measured values for different constituents with the Alberta Surface Water Quality Objectives (ASWQO; Alberta Environment, 1977) and with the Canadian Water Quality Guidelines (CWQG; CCREM, 1987). Values outside the limits identified in the ASWQO or CWQG were described as non-compliant. However, this does not imply that enforcement action is required since the limits are objectives or guidelines, not legal standards. In addition, two important conditions governing the application of the ASWQO should be kept in mind: (1) the Objectives "apply to surface waters except in areas of close proximity to outfalls"; (2) the Objectives do not apply "where the natural water quality of a lake or river does not meet some of the suggested limits", i.e., the natural levels may exceed the proposed objective (Alberta Environment, 1977).

The ASWQO for suspended solids and colour are based on an increase above "background or ambient conditions". For samples collected downstream of Hinton and Whitecourt, the background conditions were considered to be those recorded in the Athabasca River upstream of the two towns.

3. RESULTS AND DISCUSSION

3.1 BACKGROUND

3.1.1 Introduction

This report presents and interprets the results of five water quality surveys carried out on the Athabasca River system in winter, 1988 and 1989. During winter, the Athabasca River flows from the mountains in an alkaline, hardwater, clear, base flow condition. As the river progresses northeast across the province through the boreal forest, it receives natural tributary inflow, which tends to alter its major ion composition and increase its organic carbon, colour, iron and manganese concentrations. The general water quality of the Athabasca River, as well as its physical conditions and discharge patterns, has been described by Hamilton et al. (1985) and is not repeated in detail here. Since river discharge is lowest in winter, the results of this study represent a time of low dilution capacity in the river and therefore of high potential effluent impact.

The water quality data are provided in Appendices 1 to 6 and all except the trace organic data are stored in the NAQUADAT data base of the Environmental Quality Monitoring Branch. In the following sections, various water quality constituents are described and interpreted with regard to their concentrations, controlling factors, historic conditions, compliance with water quality objectives, and effect (if any) on the river's suitability for use. Information on quality assurance and river and effluent discharges are provided below.

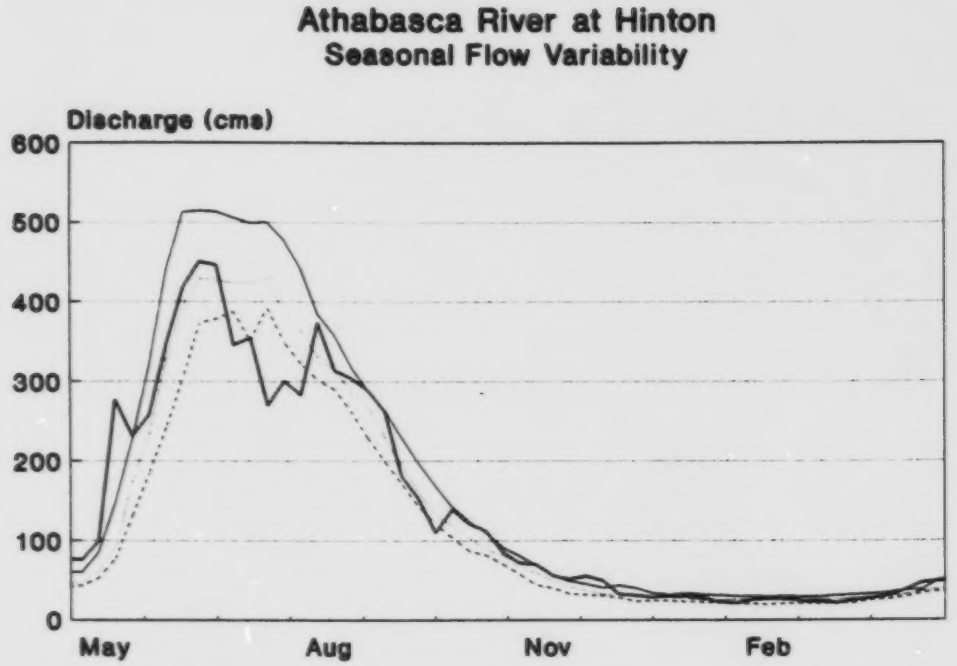
3.1.2 Quality Assurance

Quality control procedures have been outlined with regard to field procedures (Section 2.2), selected lab aspects (Section 2.3), and data scrutiny (Section 2.4). The analytical laboratories also maintain full quality control procedures, including analysis of blanks, standards and interlaboratory samples (e.g., Dieken et al., 1988). Other pertinent results of the quality control measures are outlined in Appendix II and are taken into account when interpreting the data for each water quality variable.

3.1.3 Discharge and Ice Conditions

Flows in the Athabasca River system have been described by Bothe (1982), Hamilton et al., (1985), and Bothe and Siemonsen (1989), and are reported annually by Environment Canada (e.g., Environment Canada, 1987). The seasonal flow regime in the Athabasca River is similar to other unregulated rivers in Alberta. Flows are highest during June and July and lowest from January to March (Figure 2). Mean monthly flows during January to March are only 20% of mean annual flows.

In the tributaries, peak flows generally occur in May, and low flows generally occur in January and February. For both years of this study, the sampling programs were carried out during below average winter flow conditions (Table 2); flows were about 70% of mean winter flows. Flows measured during the surveys are included in Appendices 1 to 5. For survey 88-1, flows in the Athabasca River, at Athabasca and Ft. McMurray, and in the Clearwater River were quite close to, or less than the $7Q_{10}$ flows (the average flow for a 7-day period, which is so low as to have a probability of occurrence in only one year in ten).



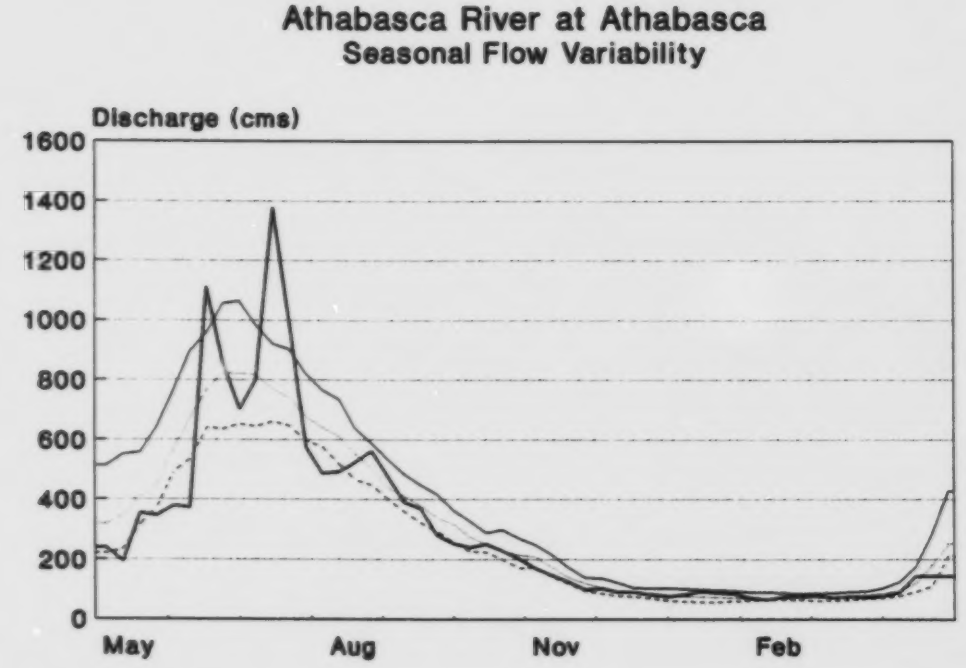


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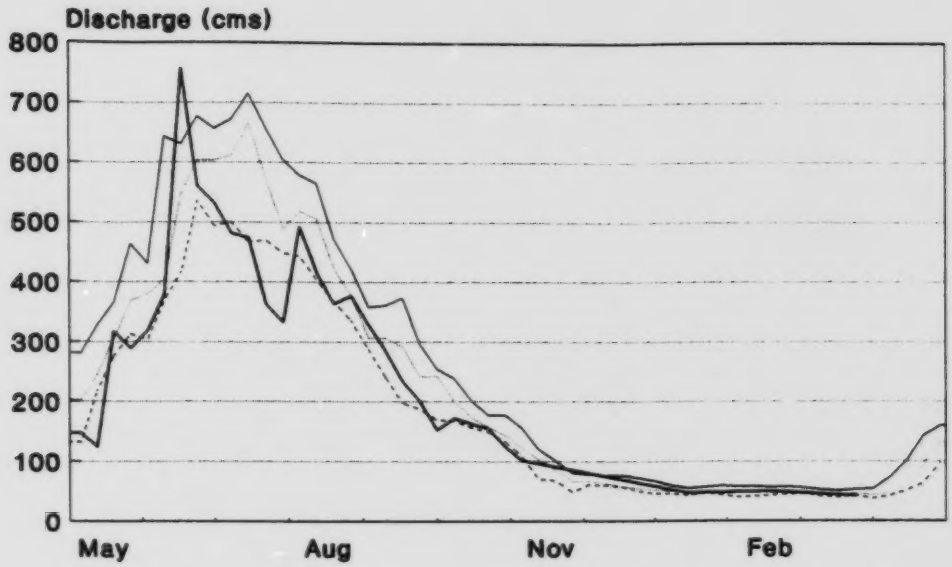
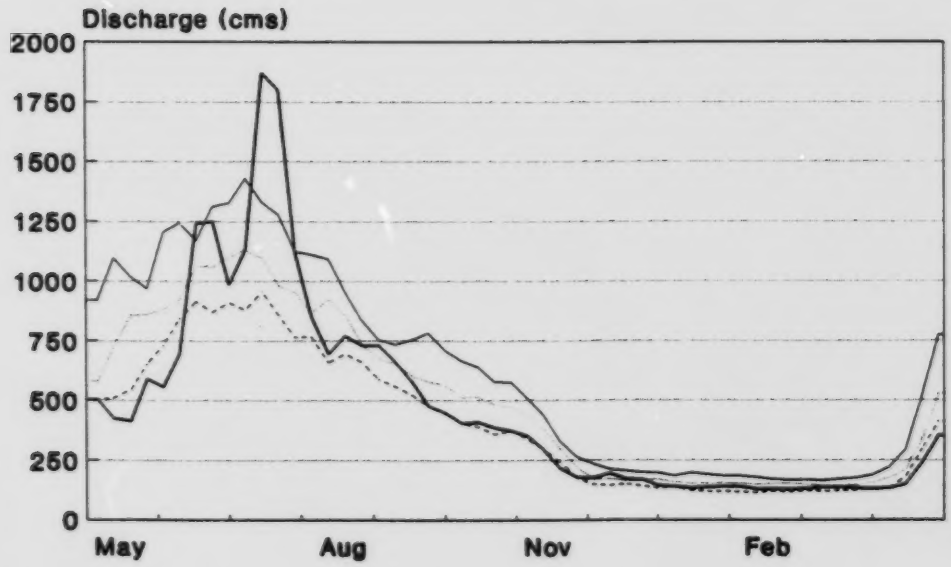
Figure 2 Seasonal Flow Variability

Athabasca River at Whitecourt
Seasonal Flow Variability



Athabasca River below Fort McMurray
Seasonal Flow Variability



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bility at Selected Sites in the Athabasca River.

TABLE 2. Winter and low flow discharges in the Athabasca River system.

SITE	MEAN WINTER	% OF AR @ EMBARRAS	ANNUAL $7Q_{10}$	INSTANTANEOUS DISCHARGE DURING SURVEY				
				88-1	88-2	89-1	89-2	89-3
AR at Hinton	33.0	-	16.0	25.1	31.4	31.3	-	28.0
Berland R.	-	-	-	-	-	-	-	-
McLeod R.	6.0	2.9	1.6	3.7	7.5	4.8	4.8	4.6
Pembina R.	6.1	2.9	1.4	1.2	1.4	2.8	3.0	2.9
Lesser Slave	32.7	15.7	11.6	12.3	12.6	25.1	23.9	22.7
AR at Athabasca	94.0	-	53.0	55.0	72.4	87.3	69.8	75.2
La Biche R.	3.0	1.4	-	-	-	0.9	-	0.4
Clearwater R.	54.1	24.0	35.2	35.6	42.3	49.2	-	46.3
AR at Fort McMurray (d/s of Clearwater R.)	176.0	-	114.0	88.6	130.0	128.0	-	138.0
Firebag R.	9.1	4.4	6.1	-	-	9.3	-	6.7
AR at Embarras	208	-	-	-	137	-	144.7	-
Richardson R.	11.7	-	-	-	-	10.6	-	10.1

Discharge as m^3/s. Measurement by Technical Services Division, Alberta Environment or Water Survey of Canada.
AR Athabasca River
Dash (-) indicates not measured and/or not calculated.
Mean winter flows calculated from January to March, inclusive for period of record.
$7Q_{10}$ flows from Bothe and Siemonsen, 1989.

Open-water leads exist on the river during winter, particularly from Hinton to the Ft. Assiniboine area, and at the Grand Rapids (Figure 1). The extent of the open-water leads likely varies with the severity of the winter. Thermal input from the Hinton combined effluent (HCE) and the Millar Western Pulp Ltd. effluent (MWPLE) causes open-water leads downstream of Hinton and Whitecourt, respectively. The extent of open water in the Hinton to Ft. Assiniboine reach was inspected from the air during surveys 88-1 and 88-2 and marked onto 1:50,000 scale maps by EMA (EQMB, Alberta Environment, unpublished data). During 18 to 20 February, 1989, 1:10,000 scale, black and white, stereo-pair photographs were taken of the Hinton to Pembina River reach to document open water leads. The photos are available from the airphoto library of the Department of Forestry, Lands and Wildlife.

3.1.4 Effluents

The main effluents that discharged to the Athabasca River are listed in Table 3, and their locations are shown on Figure 1. The Weldwood of Canada Ltd. bleached kraft pulp mill at Hinton treats its wastewater plus the Town of Hinton municipal sewage in a combined treatment system. The pulp mill at Whitecourt commenced operation in the summer of 1988 and is operated by Millar Western Pulp Ltd. The facility is a chemi-thermomechanical pulp (CTMP) mill, that utilizes sodium sulphite and sodium hydroxide to process pulp. Effluent discharge from MWPL is about 15% of the HCE (Table 3).

Three sewage treatment plants (Whitecourt, Athabasca, and Ft. McMurray) discharge directly into the Athabasca River. The Suncor Oil Sands plant discharges treated wastewater downstream of Ft. McMurray.

TABLE 3. Effluents to the Athabasca and Lesser Slave rivers.

EFFLUENT	TYPE AND TREATMENT	APPROXIMATE DISCHARGE m^3/s (continuous)
Hinton Combined Effluent (HCE)	Bleached kraft pulp mill wastewater plus (~95%) municipal sewage (~5%); combined secondary treatment	1
Millar Western Pulp Ltd: (MWPL), at Whitecourt (started Summer 1988)	Chemi-thermo-mechanical pulp (CTMP) mill effluent; secondary treatment	0.13
Whitecourt Sewage Treatment Plant (STP)	Municipal sewage; secondary treatment	0.04
Slave Lake STP, on Lesser Slave River	Municipal sewage; secondary treatment	0.03
Athabasca STP	Municipal sewage; secondary treatment	0.01
Ft. McMurray STP	Municipal sewage; secondary treatment	0.15
Suncor Inc. process effluent	Oil sands extraction and upgrading plant, process wastewater (not tailings); secondary treatment.	0.25

Other effluents in the basin discharge to tributaries and are thereby effectively sampled as part of the tributary, e.g., Edson Sewage Treatment Plant (STP) on the McLeod River, Barrhead STP on the Pembina River, and Slave Lake STP on the Lesser Slave River. Water quality and discharge data for the effluents are in Appendices 1 to 6.

3.2 Dissolved Oxygen and Biochemical Oxygen Demand

Dissolved oxygen (DO) is required by aquatic organisms for aerobic respiration. At low concentrations, it can become a limiting factor for the maintenance of aquatic life. The lower lethal limit is species-specific. The effects of toxins may be magnified, if the aquatic organism is under stress due to low dissolved oxygen (CCREM, 1987).

Dissolved oxygen concentrations in surface waters are affected by photosynthetic activity, biological respiration, temperature, and reoxygenation from the atmosphere. During winter, photosynthetic activity is minimal, and reoxygenation is limited to open-water leads or rapids. Bacterial decomposition of organic materials and chemical oxidation of inorganic and organic materials can reduce or totally deplete DO in rivers in winter.

Biochemical oxygen demand (BOD) is a measure of the amount of oxygen required for aerobic microorganisms to oxidize organic matter to a stable inorganic form (CCREM, 1987); BOD may also measure the oxygen used to oxidize forms of nitrogen. Biochemical oxygen demand in a water sample is generally measured as the amount of oxygen consumed in laboratory tests over a five-day period at 20°C.

In both years of the study, dissolved oxygen concentrations in the headwaters upstream of Hinton were about 11.5 mg/L; the saturation

concentration would be about 13 mg/L. Dissolved oxygen concentrations in the reach between Hinton and Whitecourt declined to about 10 mg/L (Table 4, Figure 3). The decline in DO concentrations was most likely attributable to oxygen demanding material (BOD) discharged from the HCE (Table 5), and the oxygen demand of the river bed. The latter, often referred to as sediment oxygen demand (SOD), appears to be increased by pulp mill effluents (Casey and Noton, 1989). The sag in DO concentrations downstream of Hinton was likely greater in the past because (1) historic data collected upstream of Whitecourt have indicated lower DO concentrations (Figure 3), and (2) in previous years, the Hinton pulp mill discharged a much higher BOD load (Clayton, 1972; EQMB, Alberta Environment, unpublished data).

Upstream of Smith, DO concentrations declined to 8.3-9.1 mg/L in 1988 and to 6.0-7.7 mg/L in 1989. The difference between the two years was most likely attributable to a combination of BOD in the water column and enhanced SOD from the river bed, both due to the new effluent load from the MWPL mill at Whitecourt. The BOD load from MWPLE was about an order of magnitude greater than the total of the McLeod River and the Whitecourt STP effluents (Table 5), which also discharge in that area. In the reaches from the Town of Athabasca to Grand Rapids and Ft. McMurray to Lake Athabasca, DO concentrations decreased gradually, due to a combination of water column BOD and sediment oxygen demand.

A key feature within the Athabasca River is the increased DO concentrations downstream of Smith and Grand Rapids, due to DO loading from the Lesser Slave River (Table 4) and reoxygenation at the Grand Rapids, respectively (Figure 3).

TABLE 4. Winter dissolved oxygen concentrations at selected sites in the Athabasca River system.

	1988				1989					
	Survey 1		Survey 2		Survey 1		Survey 2		Survey 3	
	Date	DO	Date	DO	Date	DO	Date	DO	Date	DO
AR u/s Hinton	1 Feb.	11.7	4 Mar.	11.6	9 Jan.	11.7	-		13 Feb.	11.1
AR u/s Berland R.	4 Feb.	9.7	5 Mar.	10.1	10 Jan.	10.6	-		14 Feb.	9.8
Berland R. mouth	5 Feb.	10.6	5 Mar.	10.5	10 Jan.	8.6	-		14 Feb.	9.6
AR u/s Whitecourt	6 Feb.	9.8	6 Mar.	9.7	12 Jan.	10.3	26 Jan.	9.5	15 Feb.	9.5
McLeod R. mouth	6 Feb.	5.5	6 Mar.	9.7	12 Jan.	5.3	26 Jan.	4.9	16 Feb.	6.0
AR at Ft. Assiniboine	8 Feb.	9.1	7 Mar.	9.7	16 Jan.	7.6	27 Jan.	7.9	20 Feb.	6.9
AR u/s Pembina R.	-	-	-	-	16 Jan.	8.0	6 Feb.	7.8	20 Feb.	6.3
Pembina R. mouth	8 Feb.	2.2	7 Mar.	7.7	16 Jan.	2.8	6 Feb.	1.5	20 Feb.	1.5
AR u/s Smith and L. Slave R.	9 Feb.	8.3	8 Mar	9.1	18 Jan.	7.7	6 Feb.	7.4	22 Feb.	6.0
L. Slave R. mouth	9 Feb.	13.0	8 Mar.	11.3	18 Jan.	12.3	6 Feb.	12.2	22 Feb.	12.1
AR at Athabasca	11 Feb.	8.7	9 Mar.	9.6	20 Jan.	8.8	6 Feb.	7.3	23 Feb.	7.9
	1988 Lower Athabasca Survey									
AR near McMillan Lake	-	-	-	-	25 Jan.	8.1	-		1 Mar.	7.7
AR u/s of Grand Rapids	-	-	-	-	8 Feb.	7.5	22 Feb.	7.9	7 Mar.	7.2
AR d/s of Grand Rapids	-	-	-	-	8 Feb.	12.3	22 Feb.	12.2	7 Mar.	11.8
AR u/s of Ft. McMurray	19 Jan.	11.6	15 Mar.	13.6	8 Feb.	12.1	-		8 Mar.	11.8
Clearwater R. mouth	19 Jan.	12.2	15 Mar.	12.9	9 Feb.	12.4	-		8 Mar.	12.6
AR near Bitumount	19 Jan.	11.7	16 Mar.	12.1	14 Feb.	11.9	-		9 Mar.	11.6
AR at Old Fort	20 Jan.	10.2	16 Mar.	11.2	15 Feb.	10.4	-		15 Mar.	9.9
AR at Mouth	20 Jan.	9.8	17 Mar.	10.5	15 Feb.	10.0	-		16 Mar.	9.7

AR Athabasca River, u/s Upstream, d/s downstream, DO Dissolved Oxygen, mg/L, mean of 2-6 replicates. Data in Appendices 1 to 5.
Dashes indicate the site was not part of the survey.

Figure 3. Winter Dissolved Oxygen Concentrations in the Athabasca River

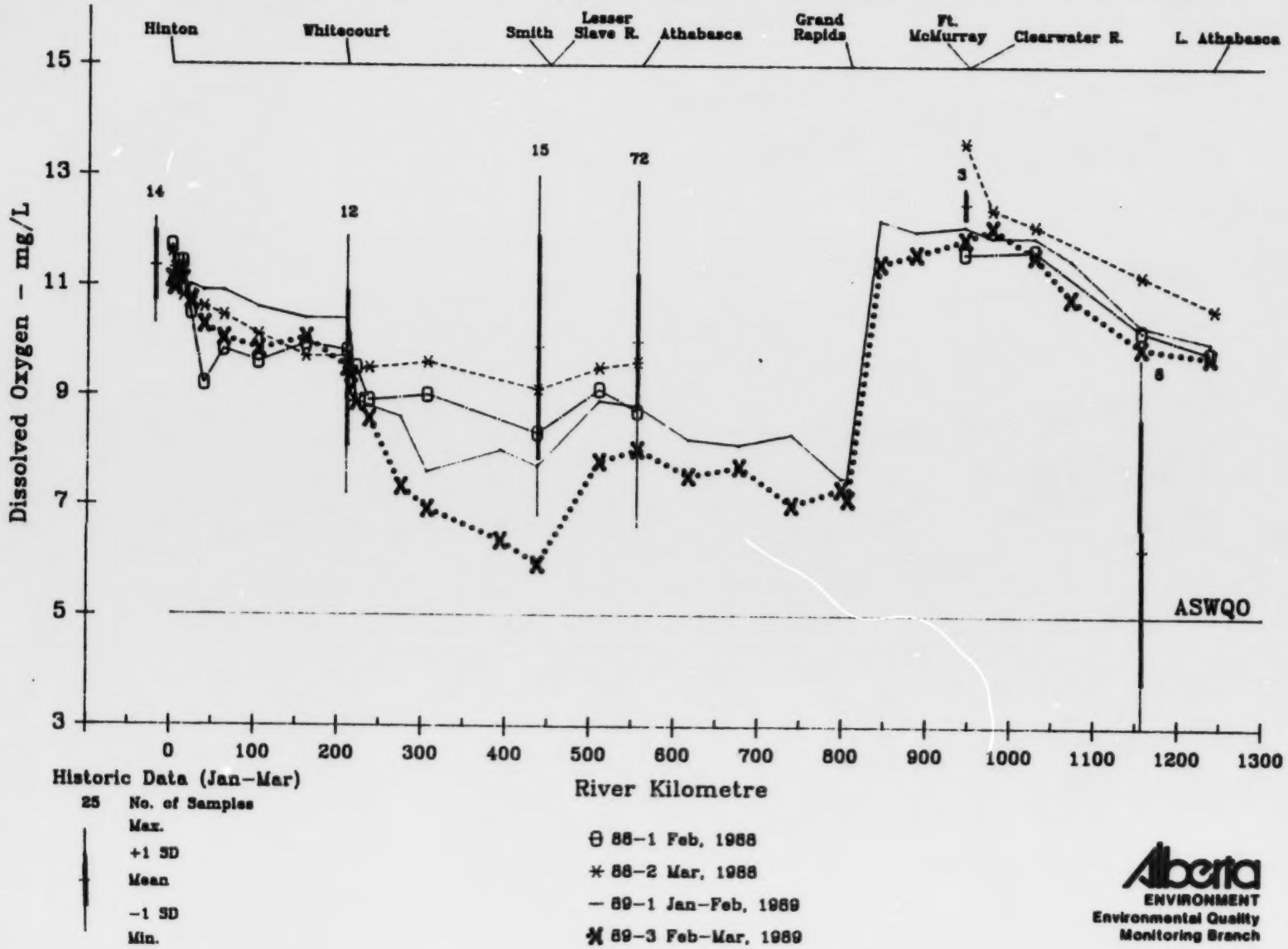

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TABLE 5. Mass load of biochemical oxygen demand at selected locations.

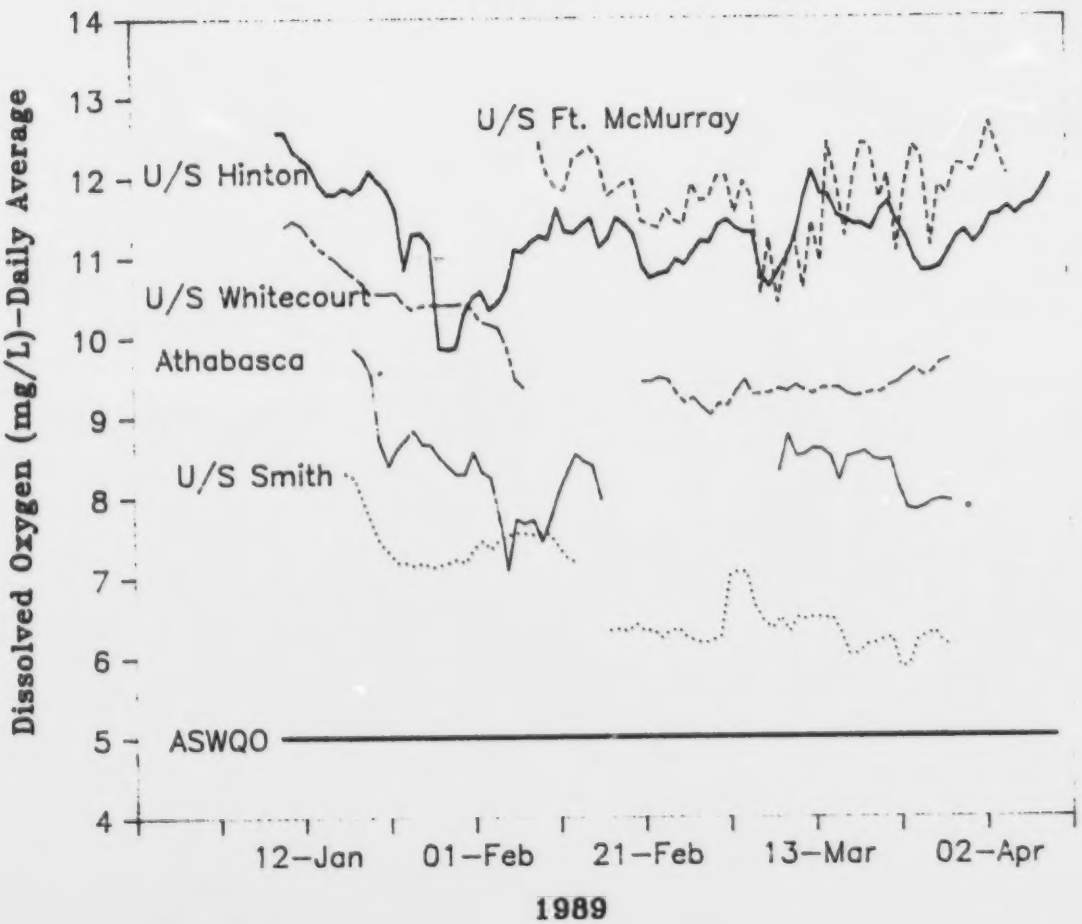
Locations	Load - kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	8,400	7,400	5,600		1,100
Inputs:					
AR u/s HCE	4,700	4,100	2,200		2,400
HCE	4,500	2,700	2,500		1,800
2. AR d/s Whitecourt (10km)	8,400*	7,000*	12,000	8,300	9,800
Inputs:					
AR u/s Whitecourt	8,300	9,700	4,900	3,000	1,800
McLeod River	310	1,300	660	140	320
MWPL effluent			7,700	6,000	6,000
Whitecourt STP effluent			20	17	24
3. AR at Athabasca			7,000	1,700	3,200
Inputs:					
AR u/s L. Slave River	6,800	5,200	4,800	1,600	8,400
Lesser Slave River	3,000	1,300	2,000	1,200	780
Athabasca STP effluent			14		16
4. AR d/s Ft. McMurray (near Bitumount)			13,000		6,000
Inputs:					
AR u/s Ft. McMurray (near Horse R.)			3,700		2,300
Clearwater River			3,800		1,400
Ft. McMurray STP effluent			360		540
Suncor process effluent			110		40

BOD: 5 day, 20°C
* AR 25 km d/s Whitecourt

Low concentrations were recorded upstream of Smith and at the Town of Athabasca in Surveys 89-2 and 89-3. Concentration minima of 6.0 mg/L at Smith and 7.3 mg/L at the Town of Athabasca were measured in grab samples; slightly lower concentrations were measured occasionally with the continuous monitors (Figure 4). The DO value at the Town of Athabasca is the second lowest value on record; winter DO has been monitored there since 1970 (n=72). Concentrations measured at Smith during 1989 were the lowest recorded, although there were fewer historic observations there (n=14) than for Athabasca. All of the historic data have been collected since the start-up of the pulp mill at Hinton.

All dissolved oxygen concentrations in the Athabasca River that were measured during this study complied with the ASWQO of 5 mg/L. The CWQG differ for warm- and cold-water biota, both of which occur in the Athabasca River (Wallace and McCart, 1984). The guidelines for warm-water biota are 6 and 5 mg/L for early and other life stages, respectively. Most reaches of the river complied with these guidelines. However, upstream of Smith, concentrations of 5.6 to 6 mg/L were recorded 17 March to 24 March 1989 (Figure 4). All DO concentrations measured previously at this site (Figure 3) were compliant with ASWQO and CWQG for warm-water biota. For cold water biota, the CWQG are 9.5 and 6.5 mg/L for early and other life stages, respectively. During 1989, as in many previous years, the entire Whitecourt to Grand Rapids reach was non-compliant with the 9.5 mg/L guideline, while for the first time on record, the reach from the Pembina River to Smith was non-compliant with the 6.5 mg/L guideline.

Figure 4. Winter Continuous Dissolved Oxygen Readings, Athabasca River.



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3.3 Total Dissolved Solids and Major Ions

Total dissolved solids (TDS) is a measure of the concentration of dissolved matter in water. The composition and concentration of TDS are important in determining the variety and abundance of aquatic biota (CCREM, 1987). A major change in the quantity or quality of TDS will affect the structure of an aquatic ecosystem.

In general, the major ions Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, $SO_4^{=}$, and HCO_3^{-} (and/or $CO_3^{=}$) account for most of the TDS in surface waters. The major ions occur naturally in water as a result of geochemical weathering of rocks and from atmospheric deposition. Carbonates are affected by CO_2 exchange between the atmosphere and water and by biological processes such as respiration and photosynthesis. In addition, industrial and municipal effluents are rich in TDS. Both kraft and CTMP mill effluent are rich in Na^{+} and $SO_4^{=}$ and kraft mill effluents contain high concentrations of Cl^{-}. Most of the major ions are considered conservative; the main processes affecting their concentrations are dilution and downstream transport. Some, specifically Ca^{++} and HCO_3^{-}, are reactive; their concentrations may be affected by changes in pH and temperature (e.g., $CaCO_3$ cycle).

During Surveys 89-1 and 89-3, TDS concentrations were fairly consistent (~ 250 mg/L) along the length of the river (Figure 5). In 1988, TDS was measured only in the lower Athabasca River; concentrations in 1988 were similar to those in 1989. Total dissolved solid solid concentrations increased about 20 mg/L downstream of Hinton and Whitecourt, primarily as a result of TDS loading from the HCE and McLeod River, respectively (Table 6). Total dissolved concentrations declined

Figure 5. Winter Total Dissolved Solids Concentrations in the Athabasca River

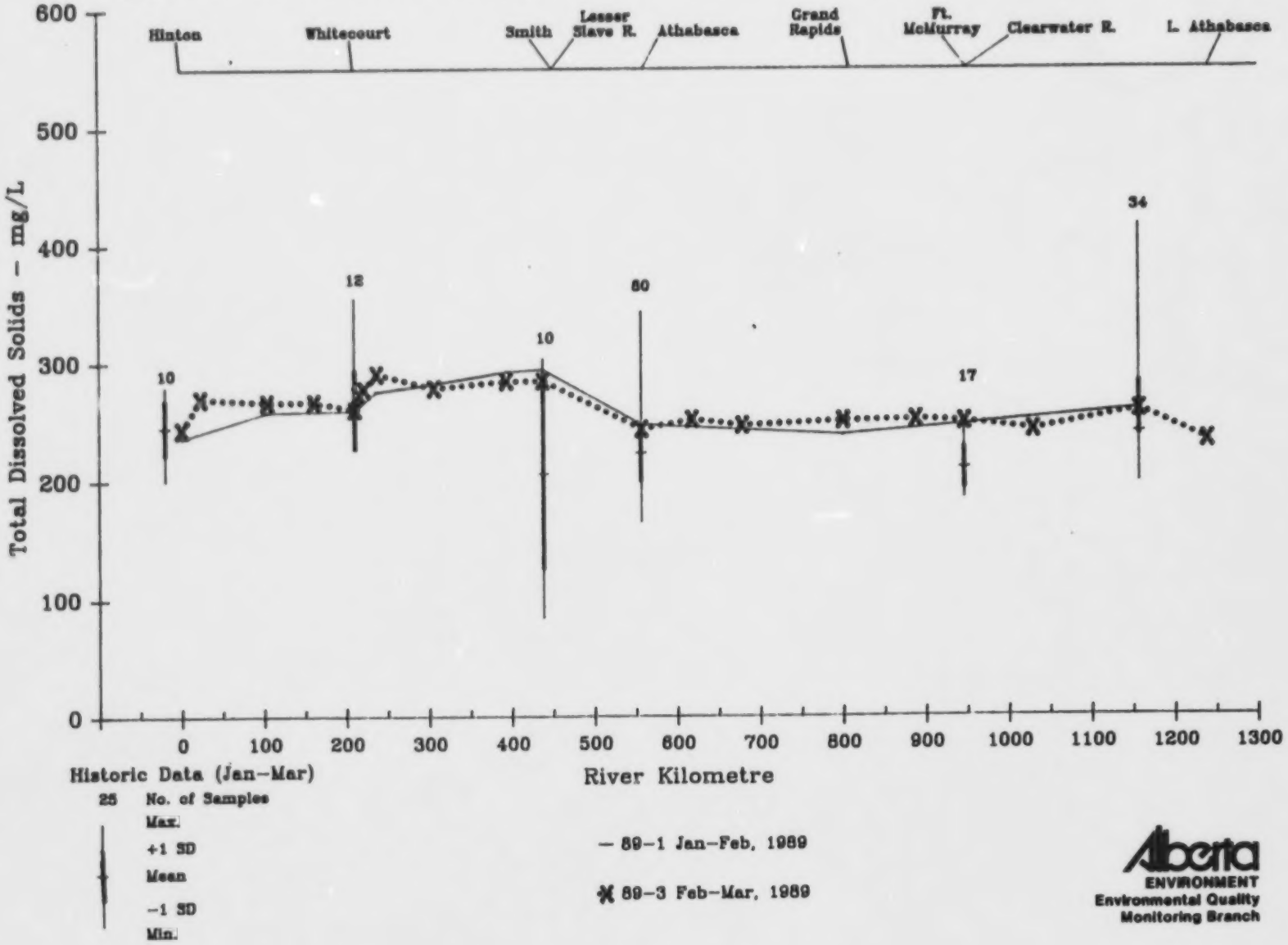

TABLE 6. Mass load of total dissolved solids at selected locations.

Locations	Load - 1000 kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)					670
Inputs:					
AR u/s HCE			640		590
HCE			91		89
2. AR d/s Whitecourt (25km)			1,100	1,100	1,300
Inputs:					
AR u/s Whitecourt			940	930	1,000
McLeod River			140	130	120
MWPL effluent			31	29	35
Whitecourt STP effluent			2	2	2
3. AR at Athabasca			1,900	1,500	1,600
Inputs:					
AR u/s L. Slave River			1,600	1,300	1,300
Lesser Slave River			250	250	220
Athabasca STP effluent					1
4. AR d/s Ft. McMurray (near Bitumount)	2,300	2,800			2,900
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	1,500	2,000	1,600		1,500
Clearwater River	620	690	740		710
Ft. McMurray STP effluent		7			4
Suncor process effluent		14			10

below Smith because of dilution by the Lesser Slave River (TDS ~ 115 mg/L).

Concentrations of TDS measured during this study were well within the range recorded in previous winters (Figure 5). The highest TDS concentration in the Athabasca River in this study (294 mg/L) was recorded upstream of the confluence of the Lesser Slave River during survey 89-1. That value is well below the CWQG for raw water for drinking water supplies (500 mg/L) and for livestock watering (3,000 mg/L). There are no ASWQO for TDS.

Similar to most other fresh surface waters in Alberta, Ca^{++} and HCO_3^- are the dominant cation and anion, respectively, in the Athabasca River. In the upper reaches of the river, the ranking for cations, based on mEq/L, is $Ca^{++}>Mg^{++}>Na^{+}>K^{+}$ and for anions is $HCO_3^->SO_4^{=}>Cl^-$ (Figure 6; Hamilton et al., 1985). The Clearwater River contributes nigh Na^+ and Cl^- loads to the Athabasca River at Ft. McMurray, such that in the lower reaches of the Athabasca the ranking for cations is $Ca^{++}>Na^{++}>K^{+}>Mg^{++}$ and for anions is $HCO_3^->Cl^-_>SO_4^{=}$.

Of the major ions, Na^+ and Cl^- concentrations changed most dramatically along the river (Figures 7, 8). High loading from the HCE increased Na^+ concentrations in the Athabasca River approximately 5-fold relative to upstream levels and increased Cl^- concentrations approximately 15-fold (Tables 7 and 8). A further increase in Na^+ concentrations was observed downstream of Whitecourt due to loading from the McLeod River and MWPL effluents. This increase was greatest in 1989, the first winter MWPL operated. The most dramatic feature of the Na^+

Figure 6. Major Ion Composition Along the Athabasca River

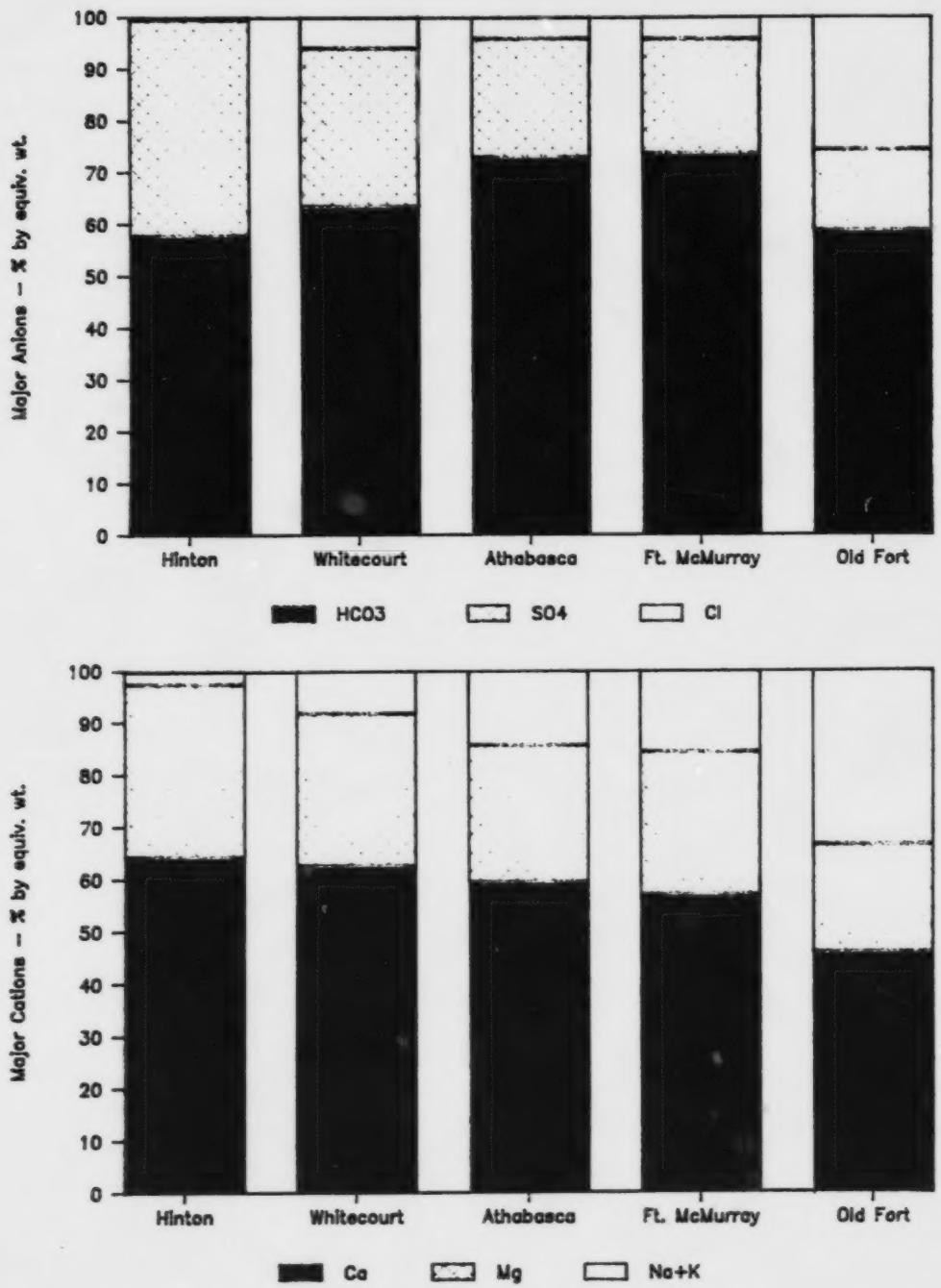

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Figure 7. Winter Sodium Concentrations in the Athabasca River

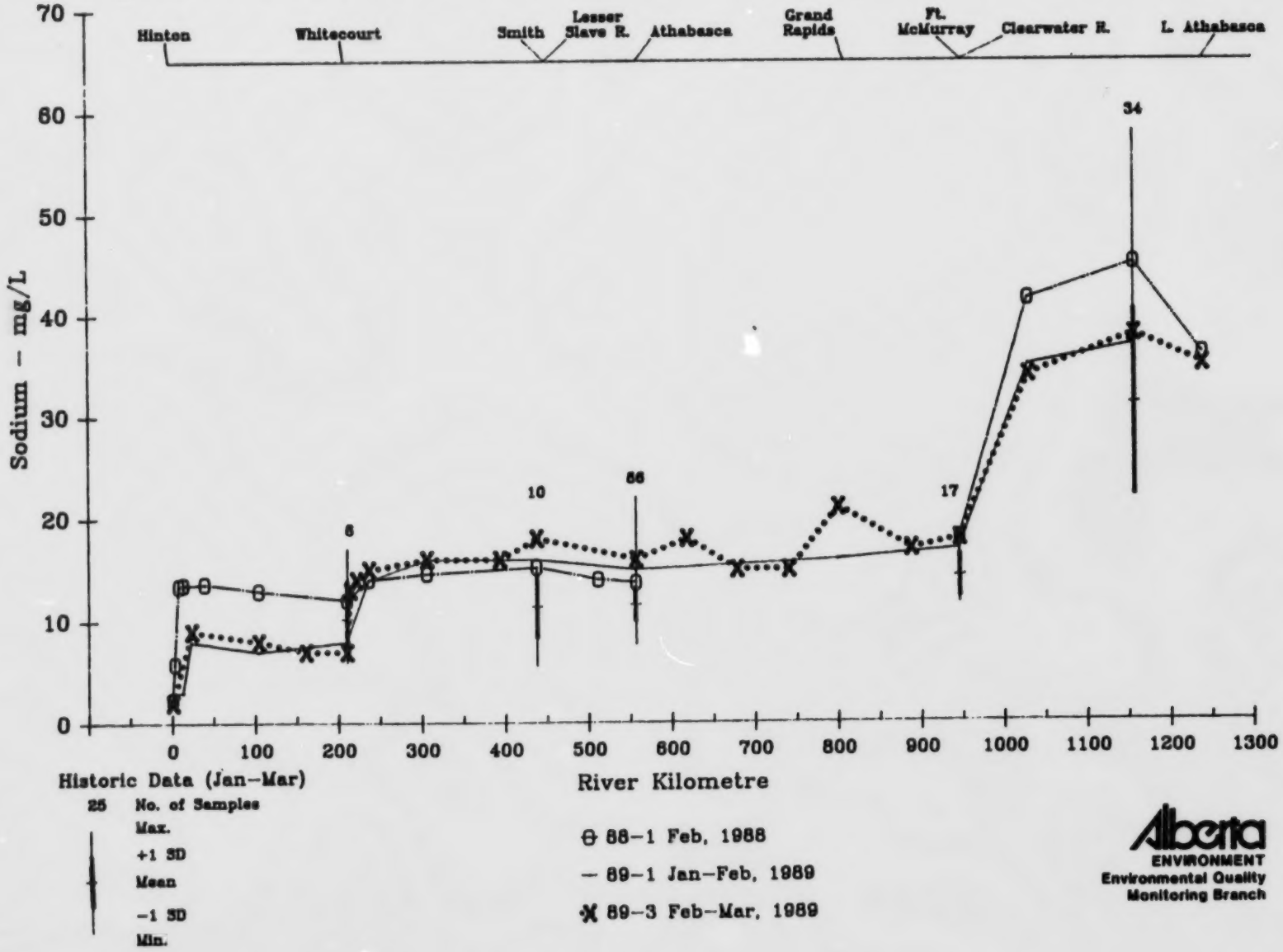


Figure 8. Winter Chloride Concentrations in the Athabasca River

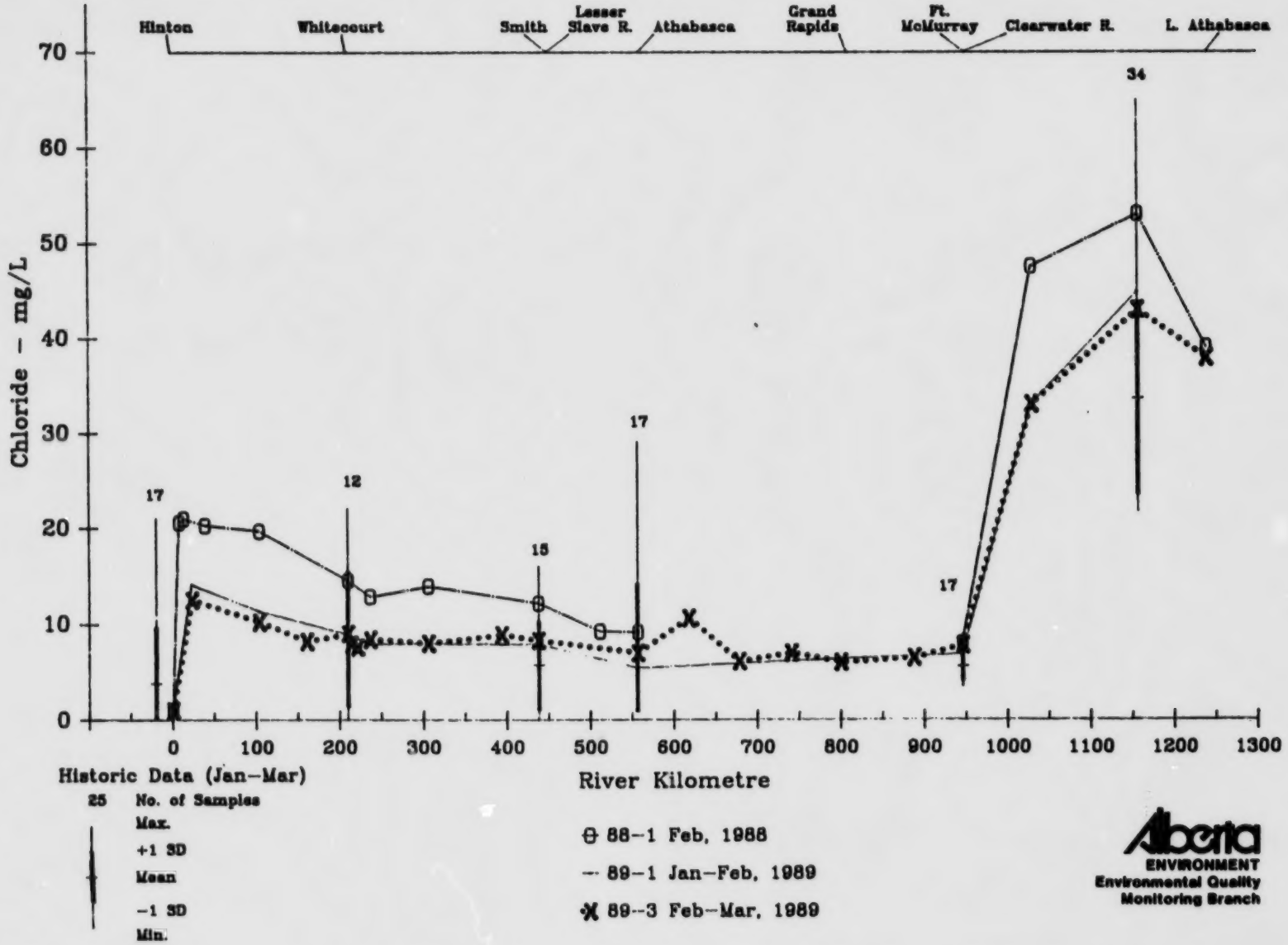


TABLE 7. Mass load of sodium at selected locations.

Locations	Load - 1000 kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)			22		23
Inputs:					
AR u/s HCE	5.0		7.2		4.8
HCE	24		23		20
2. AR d/s Whitecourt (25km)	63		57		65
Inputs:					
AR u/s Whitecourt	50		29	30	27
McLeod River	9.9		13	11	11
MWPL effluent			10	9.7	12
Whitecourt STP effluent			0.3	0.3	0.3
3. AR at Athabasca	65		110	84	100
Inputs:					
AR u/s L. Slave River	57		86	76	84
Lesser Slave River	9.5		15	14	14
Athabasca STP effluent			0.1		0.1
4. AR d/s Ft. McMurray (near Bitumount)	320	360	390		410
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	82	130	110		110
Clearwater River	150	160	180		180
Ft. McMurray STP effluent		1.3	2.3		0.9
Suncor process effluent		3.0	2.2		1.9

TABLE 8. Mass load of chloride at selected locations.

Locations	Load - 1000 kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)			39		31
Inputs:					
AR u/s HCE	2.2		2.4		2.4
HCE	47		37		31
2. AR d/s Whitecourt (25km)	58		32	38	37
Inputs:					
AR u/s Whitecourt	61		32	37	35
McLeod River	0.7		0.6	0.7	0.6
MWPL effluent			0.3	0.3	0.4
Whitecourt STP effluent			0.3	0.2	0.3
3. AR at Athabasca	43		41	39	46
Inputs:					
AR u/s L. Slave River	45		43	36	39
Lesser Slave River	1.7		2.4	2.1	2.2
Athabasca STP effluent			0.1		0.1
4. AR d/s Ft. McMurray (near Bitumount)	360	380	370		390
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	37	69	46		48
Clearwater River	220	230	230		240
Ft. McMurray STP effluent		1.1	1.6		0.6
Suncor process effluent		3.9	2.6		2.4

and Cl^- profilesin the Athabasca River was the large increase in concentrations in the lower Athabasca due to loading from the Clearwater River (Figure 7 and 8).

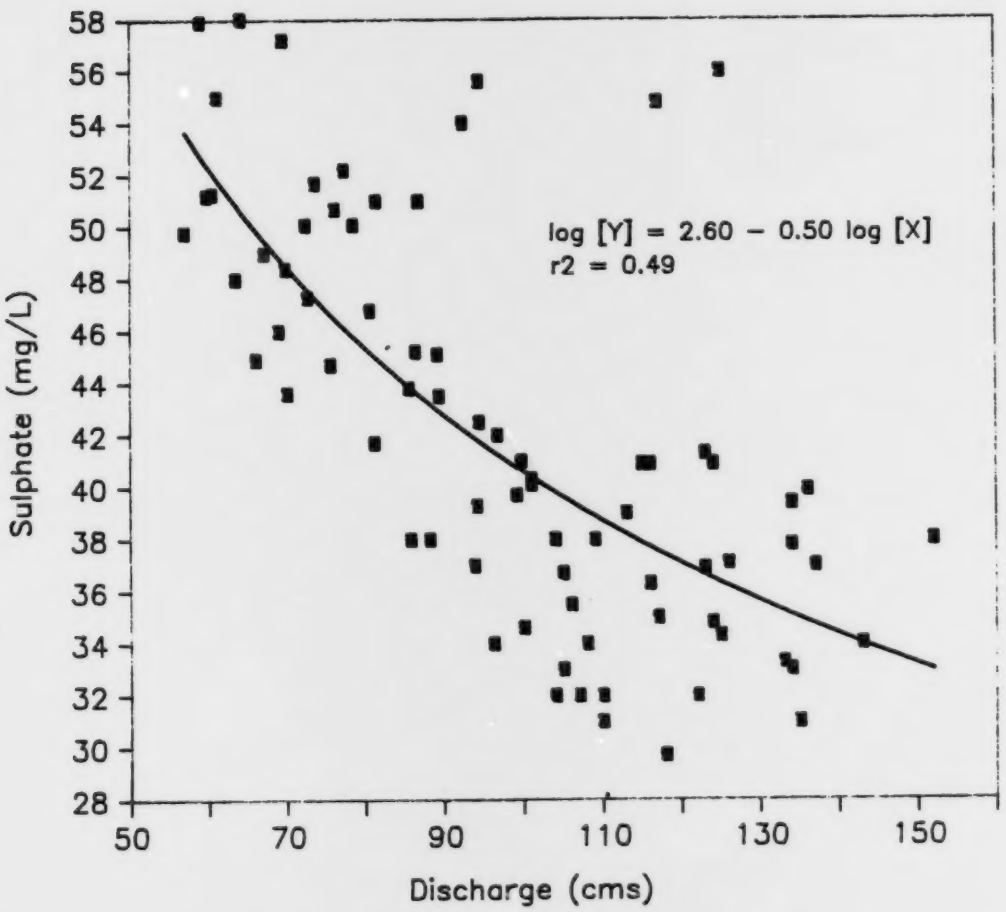
In general, sodium and chloride concentrations measured during this study were within the range reported for previous winters (Figures 7 and 8). An exception was Na^+ concentrations measured during 1989 upstream of Smith (range 16 to 18 mg/L); they were slightly higher than the historic high of 15 mg/L.

The highest Cl^- concentration recorded in the Athabasca River during this study was 53 mg/L (Survey 88-1; near Old Fort). That value is well below the CWQG of 250 mg/L for drinking water. There are no ASWQO for Cl^-. Both the ASWQO and CWQG for Na are related to the use of water for irrigation, which is negligible in the Athabasca River basin.

3.3.1 Sulphate

Winter sulphate concentrations in the Athabasca River are of interest because: (1) geochemical weathering of rocks from the Rocky Mountains imparts relatively high $SO_4^=$ concentrations to the Athabasca River upstream of Hinton, (2) $SO_4^=$ concentrations are high in pulp mill effluents (CCREM, 1987), (3) $SO_4^=$ concentrations in the river (like most other solutes) are inversely proportional to flow (r^2=0.49, P<0.01; Figure 9), thus, they will be highest in winter, and (4) the Guidelines for Canadian Drinking Water Quality (GCDWQ) aesthetic objective for $SO_4^=$ is relatively low, 150 mg/L (Health and Welfare Canada, 1987), and $SO_4^=$ is not removed through conventional water treatment processes (CCREM, 1987).

Figure 9. Winter Sulphate Concentrations vs Discharge in the Athabasca River at the Town of Athabasca, 1961–1989.



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In both years of the study, $SO_4^=$ concentrations upstream of Hinton were about 90 mg/L and decreased gradually to about 40 mg/L at the mouth of the river (Figure 10). Sulphate loads from the HCE and MWPLE contributed less than 10% of the load in the river downstream of the pulp mills (Table 9). The decrease in $SO_4^=$ concentration along most of the river was due to dilution of river water by tributaries. Sulphate in most tributaries was less than 20 mg/L (Appendices 1 to 5).

During 1988 and 1989, $SO_4^=$ concentrations upstream of Hinton were similar to historical records (Figure 10). However, $SO_4^=$ concentrations downstream of Hinton were above long-term winter averages, even though the historic data include the influence of the HCE. The values at Ft. McMurray (50 to 58 mg/L) were the highest on record. The high concentrations appear to be a result of low river and tributary flows in 1988 and 1989 (Table 2). Tributary inflow normally dilutes $SO_4^=$. During this study, the highest $SO_4^=$ concentration in the Athabasca River was recorded between Hinton and Whitecourt (Survey 88-1; 100 mg/L). That value is within the GCDWQ for an aesthetic objective of 150 mg/L.

3.4 Sulphide

Sulphate is the predominant form of sulphur (S) in aquatic environments, but during the decomposition of organic matter, S is released as hydrogen sulphide (H_2S). Under aerobic conditions, H_2S is oxidized rapidly so only low concentrations of H_2S would be expected in aerobic water (Wetzel, 1983). Reduced sulphur compounds, including inorganic and organic sulphides, are commonly found in untreated pulp mill effluents. These compounds can lead to taste and odour problems in

Figure 10. Winter Sulphate Concentrations in the Athabasca River

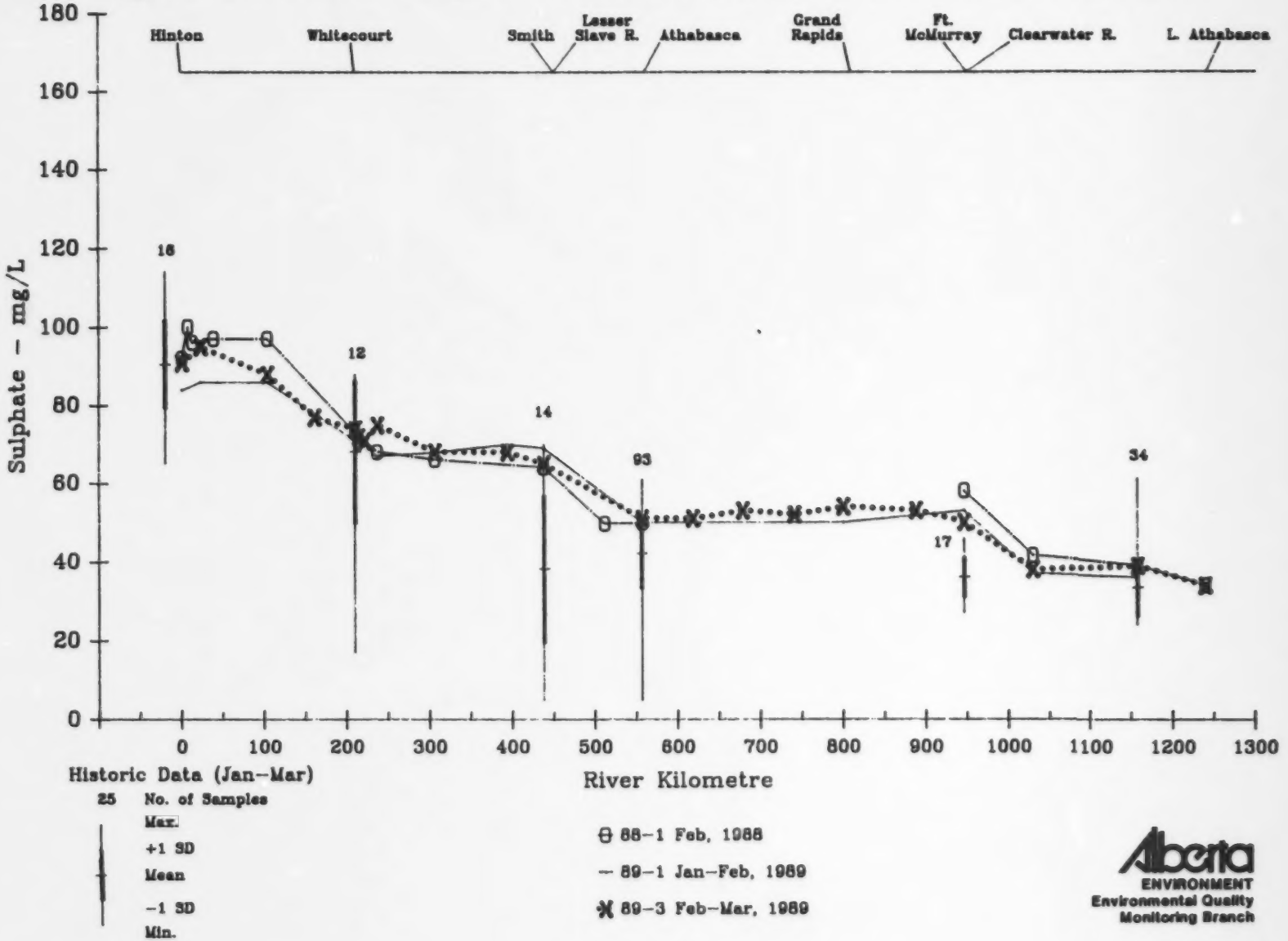

TABLE 9. Mass load of sulphate at selected locations.

Locations	Load - 1000 kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)			240		240
Inputs:					
AR u/s HCE	200		230		220
HCE	16		20		17
2. AR d/s Whitecourt (25km)	310		270	280	330
Inputs:					
AR u/s Whitecourt	310		260	250	290
McLeod River	5.8		8.6	7.4	9.2
MWPL effluent			9.4	9.8	11
Whitecourt STP effluent			0.1	0.1	0.1
3. AR at Athabasca	240		380	320	330
Inputs:					
AR u/s L. Slave River	240		370	270	300
Lesser Slave River	16		28	27	26
Athabasca STP effluent			0.1		0.1
4. AR d/s Ft. McMurray (near Bitumount)	320	370	410		450
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	270	420	350		310
Clearwater River	34	33	43		40
Ft. McMurray STP effluent		1.1	2.0		0.8
Suncor process effluent		2.3	2.4		2.2

drinking water, and can taint fish. In some cases, they are toxic to fish (Bonsor et al., 1988).

Dissolved sulphide concentrations were measured in 1989, when a new analytical method became available for measuring low levels of sulphide in water (NAQUADAT code 16200). With this method, all acid-labile forms of sulphide are converted to H_2S, and results are expressed as elemental S (mg/L). Acid-labile forms include H_2S and some metal and organic sulphides.

Sulphide concentrations in the Athabasca River and its tributaries ranged from <0.001 to 0.008 mg/L during the 1989 surveys (Appendices 3 to 5). Concentrations in effluents from the sewage treatment plants, Suncor, and MWPL were only slightly higher (0.004 to 0.011 mg/L), whereas concentrations in the HCE were much higher (0.104 to 0.169 mg/L). As a result, an increase in sulphide concentrations of 0.003 to 0.006 mg/L was observed in samples collected less than 100 km downstream of Hinton. However, the highest sulphide concentration in the Athabasca River that was measured in the 1989 winter surveys (0.008 mg/L) was much lower than the ASWQO and the CWQG for raw water for drinking water supply, both of which are 0.05 mg/L.

3.5 Silica

Silica refers to the oxides of silicon in natural waters, which are primarily SiO_2 and H_4SiO_4 (CCREM, 1987). Silica is present in most surface waters (world average 13 mg/L; Davis, 1964) and originates primarily from degradation of aluminosilicate minerals. Adsorption is the only significant mechanism of inorganic precipitation of natural silica (Wetzel, 1983). Silica is an essential micronutrient for diatom

algae; thus, high anthropogenic loads (e.g., pulp mill effluents) may contribute to increased diatom production in rivers.

Unlike many other solutes, silica concentrations in the Athabasca River do not fluctuate in synchrony with flow rates (Figure 11). This characteristic of flow-independence for silica is found in many rivers (Wetzel, 1983). An abiological buffering mechanism appears to be operational and may explain the relative stability of silica concentrations (Edwards and Liss, 1973).

For all surveys, silica concentrations in the Athabasca River were lowest (4 to 5 mg/L) in the headwaters and highest (9 to 10 mg/L) near the mouth of the river (Figure 12). Silica concentrations increased approximately 1 to 2 mg/L downstream of Whitecourt and Ft. McMurray. The increase downstream of Whitecourt was largely due to loading from the McLeod River (~ 10 mg/L; Table 10). Even though silica concentrations in the MWPLE were high (~ 130 mg/L), the load from Millar Western was only about one third of that from the McLeod River (Table 10). The increased silica concentrations downstream of Ft. McMurray were due to loading from tributaries (e.g., Clearwater, Firebag, and Richardson rivers), which have relatively high silica concentrations (~ 12 to 17 mg/L; Appendices 1 to 5). The decrease of 1 to 2 mg/L downstream of Smith was due to dilution by the Lesser Slave River (~ 1 mg/L).

Silica concentrations in the Athabasca River that were measured during this study were within the range of concentrations recorded in previous years (Figure 12). There are no ASWQO or CWQG for silica.

Figure 11. Monthly Silica Concentrations and Flow Rates in the Athabasca River at the Town of Athabasca, 1988.

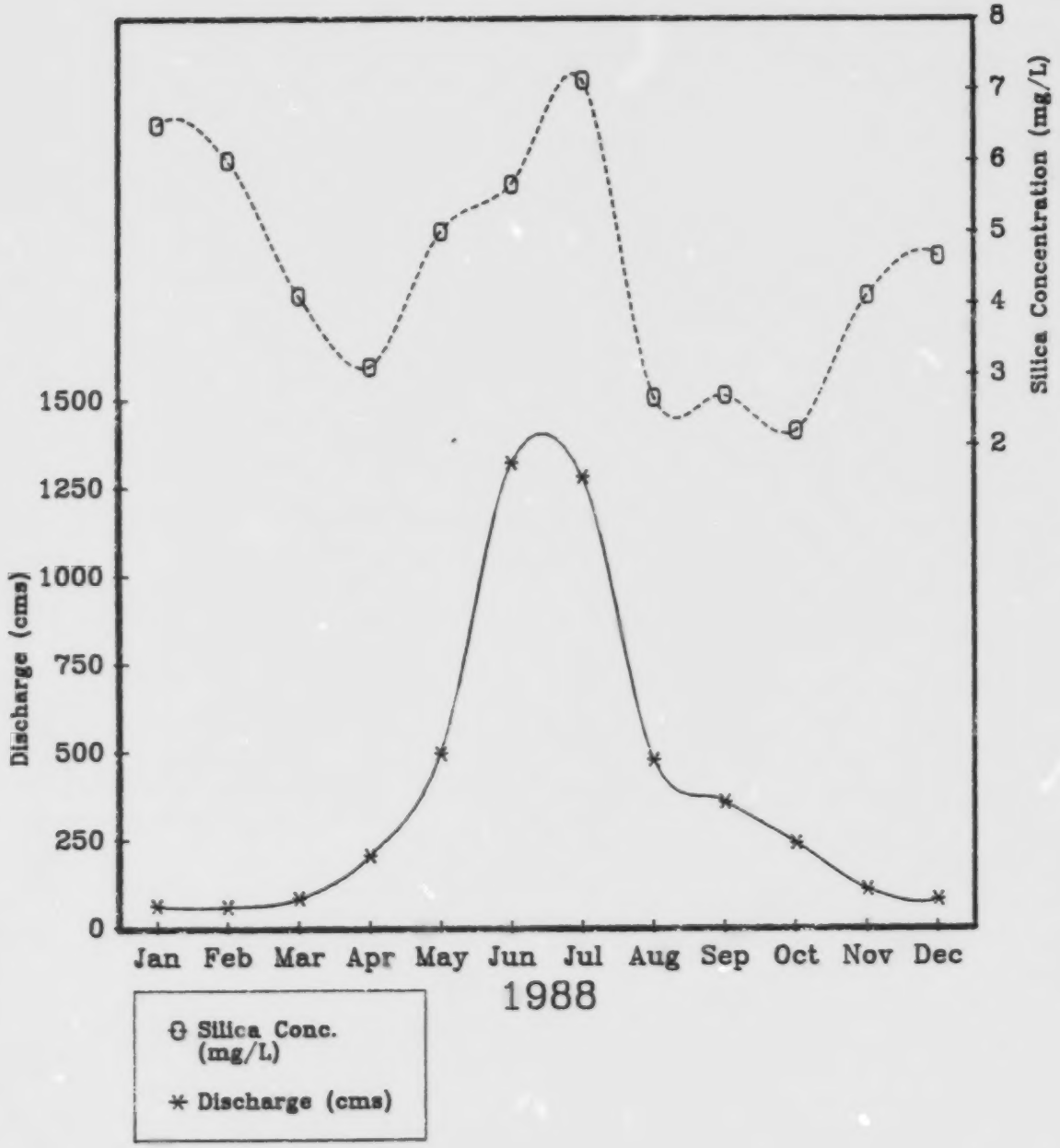

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Figure 12. Winter Silica Concentrations in the Athabasca River

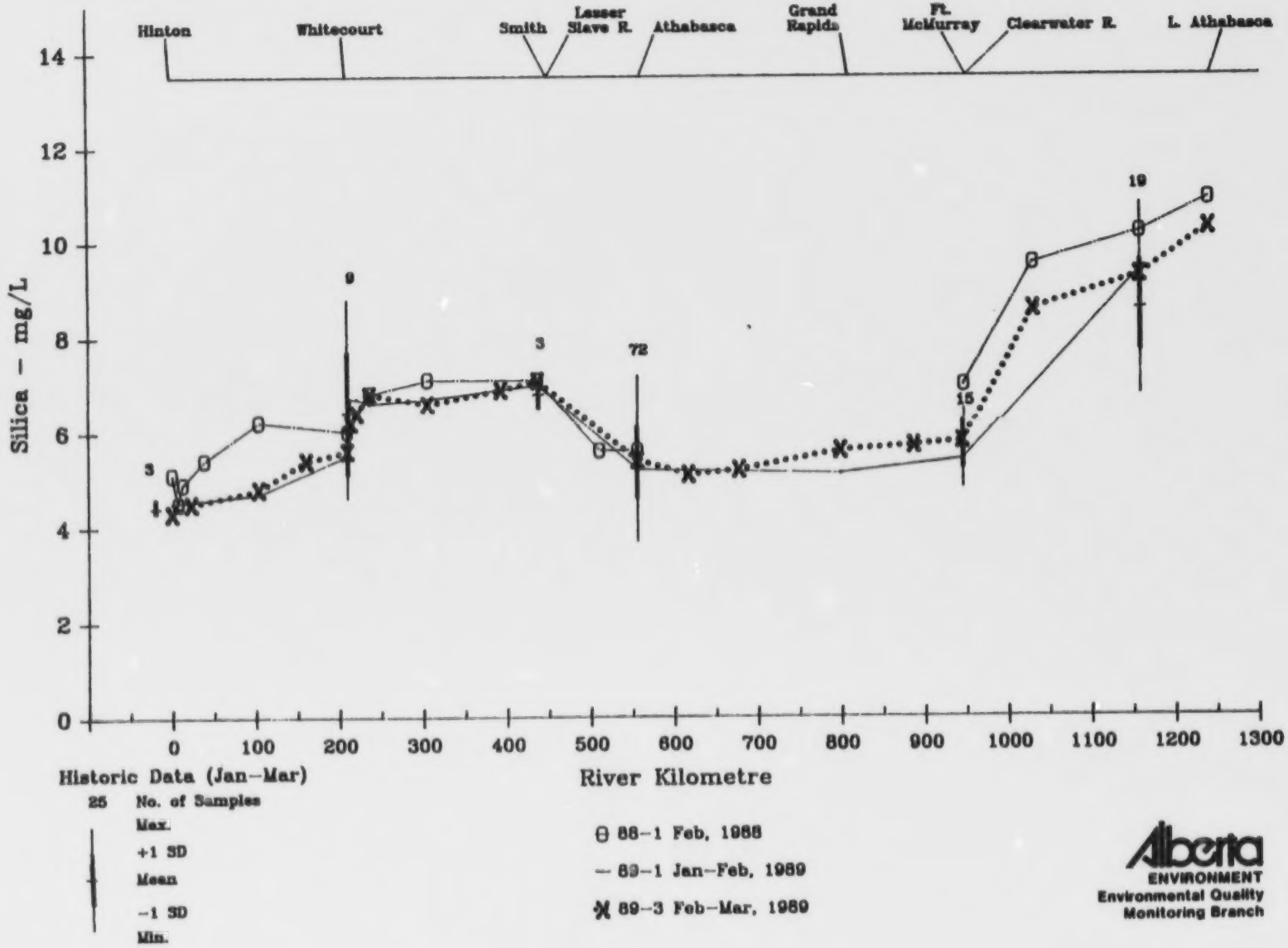


TABLE 10. Mass load of silica at selected locations.

Locations	Load - 1000 kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)					11
Inputs:					
AR u/s HCE	11		12		10
HCE	0.8		0.7		0.7
2. AR d/s Whitecourt (25km)	31		27	27	30
Inputs:					
AR u/s Whitecourt	25		20	20	22
McLeod River	3.5		4.2	4.1	3.8
MWPL effluent			1.6	1.6	1.4
Whitecourt STP effluent			0.0	0.1	0.0
3. AR at Athabasca	27		39	33	35
Inputs:					
AR u/s L. Slave River	26		38	18	33
Lesser Slave River	1.0		2.0	2.1	1.4
Athabasca STP effluent					0.0
4. AR d/s Ft. McMurray (near Bitumount)	73	87			100
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	32	38	36		36
Clearwater River	41	49	52		52
Ft. McMurray STP effluent		0.1			0.1
Suncor process effluent		0.2			0.1

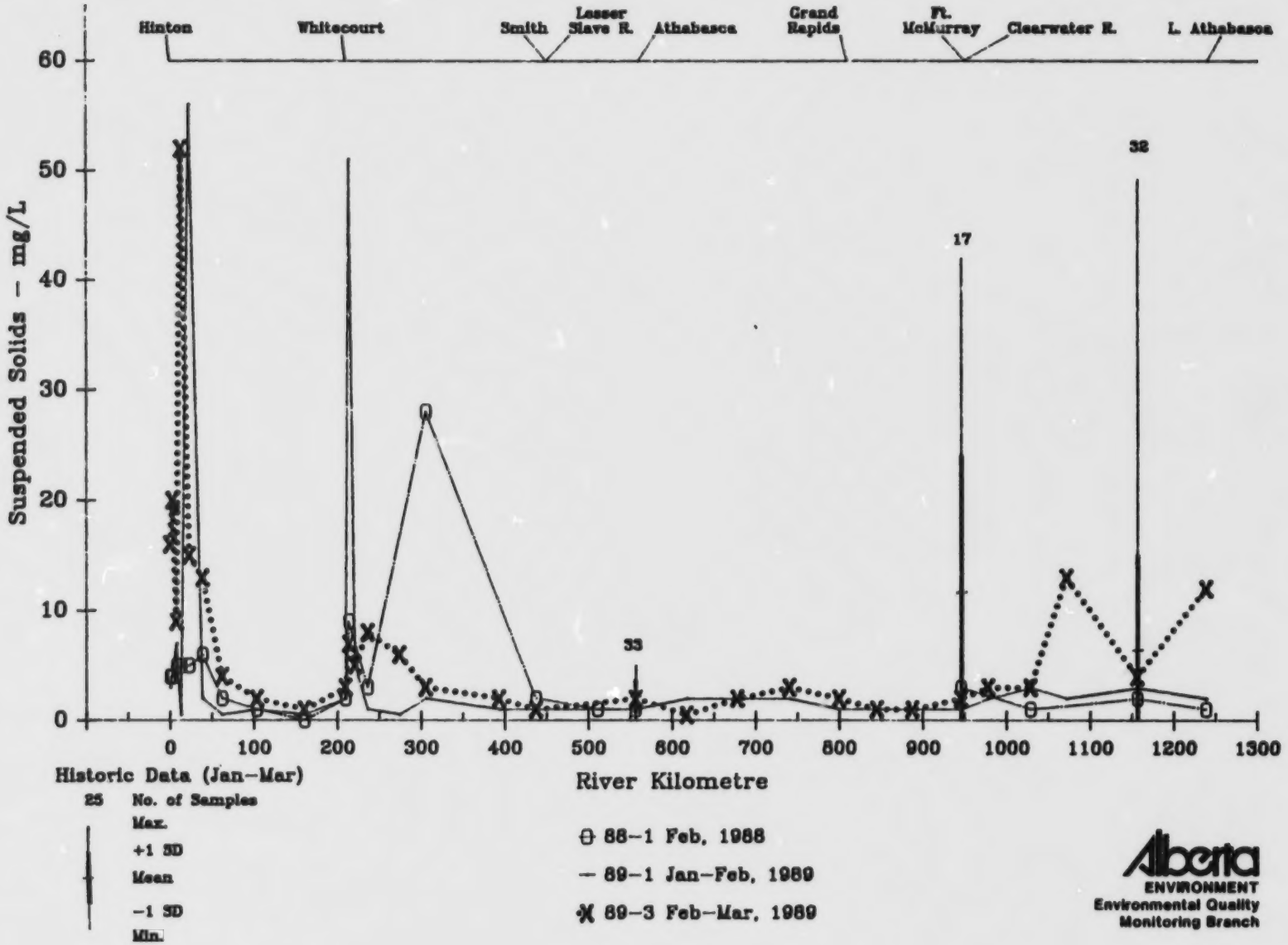
3.6 Suspended Solids and Turbidity

Concentrations of suspended solids (SS) in rivers are highly variable. Suspended solid content normally increases with flow rate as a result of scouring of river beds and banks and resuspension of particles. High SS loads can cause siltation of river beds and smothering of biota, decreased light penetration and reduced primary production, and stress to aquatic biota, which may increase susceptibility to disease (Alabaster and Lloyd, 1984). In addition, particulate matter may act as a sorption surface for organic compounds, nutrients, heavy metals, and bacterial degradation of particulate organic matter may contribute to deoxygenation of the water (CCREM, 1987).

Turbidity in water is an expression of the optical properties of water, and it is caused by the presence of suspended inorganic and organic matter. During the 1988 and 1989 winter surveys, turbidity was positively correlated to SS ($r = 0.76$, $df = 78$, $P < 0.01$), and the longitudinal pattern for turbidity was similar to that for suspended solids. Since licence limits for effluents discharging to the Athabasca River are based on SS not turbidity, only SS is discussed below.

During this study, SS concentrations upstream of Hinton were 3 to 16 mg/L. Suspended solids concentrations immediately downstream of the HCE were low during survey 88-1 (4 - 5 mg/L), but much higher during surveys 89-1 and 89-3 (up to 55 mg/L). High concentrations were recorded immediately downstream of Whitecourt in Survey 89-1 and at Ft. Assiniboine in Survey 88-1 (Figure 13). The high SS concentrations downstream of Hinton (89-1 and 89-3) and Whitecourt (89-1) may have been a result of SS discharged in the HCE and MWPLE, respectively.

Figure 13. Winter Suspended Solids Concentrations in the Athabasca River



Although the calculated SS loads in the two effluents would not have accounted for the peak concentrations, if the effluents and river were fully mixed (Table 11). The high value at Ft. Assiniboine (Survey 88-1) may be due to particulate matter bound in ice or "slush" that was inadvertently collected along with river water. Local ice jamming may accelerate water velocities and disturb sediments, thus also causing anomalously high SS concentrations.

The suspended solids concentrations measured in the Athabasca River during this study were generally low relative to values from previous winters, although historical SS data are scarce for winter months (Figure 13).

For suspended solids, the ASWQO and CWQG permit a maximum increase of 10 mg/L from ambient or background values. Most reaches of the river complied with this objective. Possible exceptions occurred downstream of Hinton during surveys 89-1 and 89-3 and downstream of Whitecourt during survey 89-1. However, these locations may be within the effluent mixing zones, in which case the ASWQO do not apply.

3.7 Oil and Grease

Oil and grease are not specific compounds, but are defined by the method of analysis, which in this case was Freon (trichloro-trifluoroethane) extraction and infrared spectrophotometry (NAQUADAT Code 06524L). This method will detect numerous organic compounds including fatty material from animal and plant life, chlorophyll, sulphur compounds, and the lighter mineral hydrocarbons (Greenberg et al., 1985). Oil and grease is a fairly non-specific parameter with regard to natural surface waters; however, it is used

TABLE 11. Mass load of suspended solids at selected locations.

Locations	Load - 1000 kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	11		160		38
Inputs:					
AR u/s HCE	8.7		8.1		39
HCE	4.9		3.5		3.3
2. AR d/s Whitecourt (25km)	11		4.1	25	35
Inputs:					
AR u/s Whitecourt	9.8		7.3	3.7	12
McLeod River	0.2		0.4	0.4	0.8
MWPL effluent			23	20	24
Whitecourt STP effluent			0.0	0.0	0.0
3. AR at Athabasca	3.2		7.5	12	13
Inputs:					
AR u/s L. Slave River	6.2		5.4	9.0	4.6
Lesser Slave River	3.2		15	12	7.8
Athabasca STP effluent			0.0		0.0
4. AR d/s Ft. McMurray (near Bitumount)	7.7	23	33		36
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	14	7.6	6.6		12
Clearwater River	0.0	15	30		24
Ft. McMurray STP effluent		0.1	0.3		0.0
Suncor process effluent		0.2	0.3		0.3

extensively in characterizing effluents and petroleum spills.

In the winters of 1988 and 1989, concentrations of oil and grease in the Athabasca River and its tributaries ranged from <0.2 mg/L to 0.6 mg/L; most were less than 0.4 mg/L. Two field blank samples in 1989 contained 0.12 and 0.47 mg/L of oil and grease, which were similar to concentrations reported for river samples. This suggests that some of the concentrations reported for the river were an artifact of sampling, handling, and/or laboratory error, and that concentrations in the river were actually lower. Hamilton et al. (1985) reported oil and grease concentrations similar to values measured in this study, but did not evaluate blank samples.

In the winters of 1988 and 1989, concentrations of oil and grease in the effluents ranged from 0.4 to 1.7 mg/L for the sewage treatment plants, 0.4 to 0.5 mg/L for the HCE, 2.5 to 4.1 mg/L for the MWPL effluent, and 3.3 to 3.7 mg/L for the Suncor Oil Sands process effluent. No effect on downstream river concentrations was apparent from any of these effluents; this observation is consistent with those from previous studies (Hamilton et al., 1985; Corkum, 1985).

The ASWQO for oil and grease states that it should be "substantially absent, no irridescent sheen" (Alberta Environment, 1977); the CWQG for recreational water quality states that it should not be detectable by sight or smell. No such "sheens" or oil odours were apparent in open water or holes that were drilled through the ice during the winter surveys.

3.8 Phenolic Compounds

The term 'phenolic compounds' refers to a family of organic compounds which possess a benzene ring on which one or more hydroxyl groups are attached. Phenol itself consists of one benzene ring with one hydroxyl group. The benzene ring can undergo a variety of substitutions (McNeely et al., 1979). The analytical method (NAQUADAT code 06537L) used to determine phenol concentrations is accurate in determining the quantity of phenol, but not the quantity of all phenolic compounds (Greenberg et al., 1985).

Most of the information about the fate of phenolics in aquatic environments refers to the compound phenol (CCREM, 1987). The major fates of phenols are probably photo-oxidation, oxidation, and microbial degradation. Phenolic compounds may occur naturally in trace amounts (usually <0.002 mg/L) in aquatic environments, because many phenols are decomposition products of aquatic plants and decaying vegetation (CCREM, 1987). Higher concentrations may occur in areas where pulp mills and sewage treatment plants discharge their effluents. Phenolics are of concern because of their propensity to taint fish, to cause taste and odour problems in drinking water, and at high concentrations to be toxic to aquatic life. The lowest observed effect level for phenols compiled by CCREM (1987) was 0.070 mg/L.

In both years of this study, phenolics were not detected upstream of Hinton (Figure 14). However, downstream of Hinton, they were detected at concentrations of about 0.005 and 0.01 mg/L in 1988 and 1989, respectively, due to discharge from the HCE (Table 12). The impact of the HCE on phenolic concentrations in the Athabasca River has been

Figure 14. Winter Phenolic Concentrations in the Athabasca River

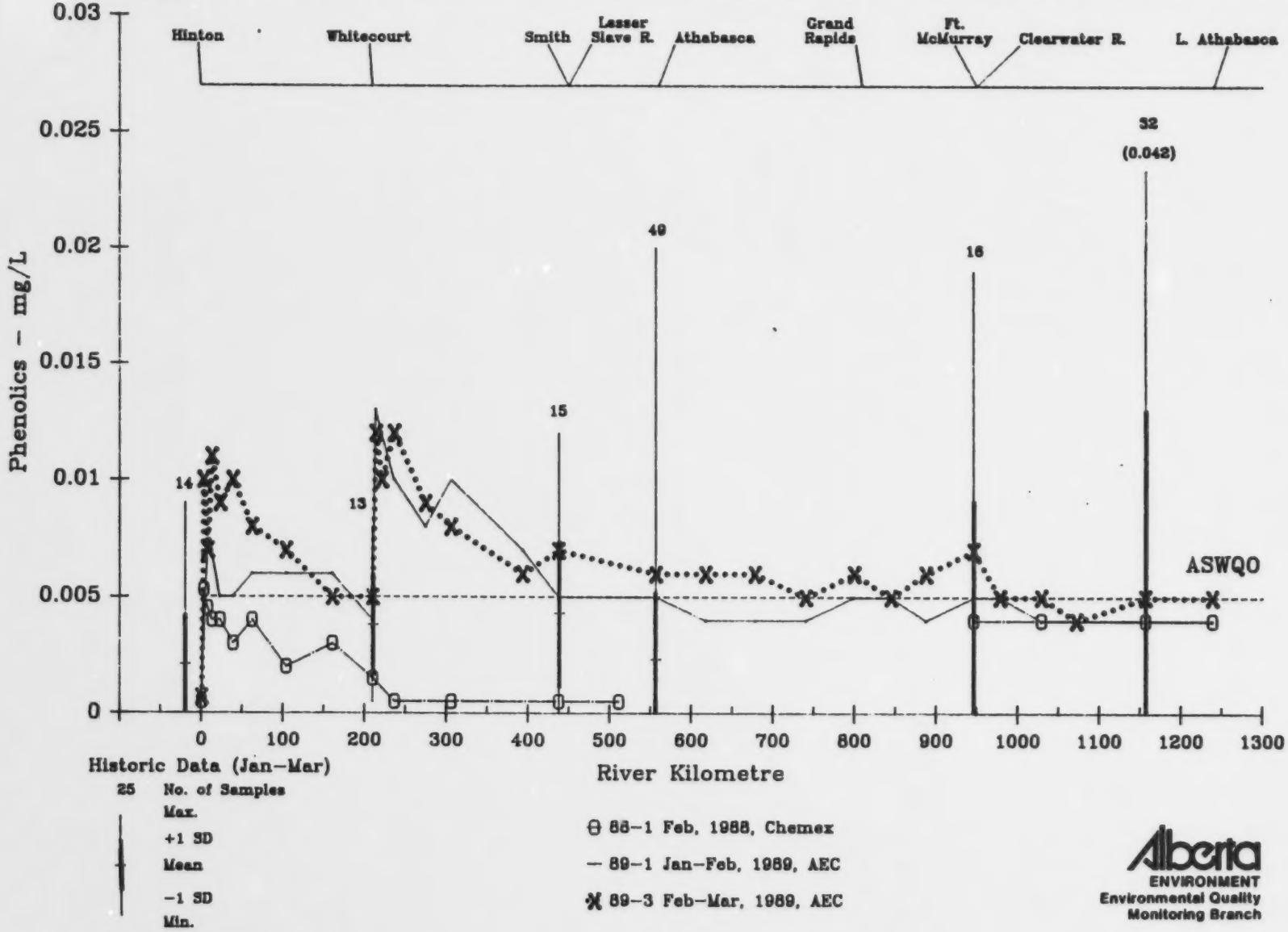


TABLE 12. Mass load of phenolics at selected locations.

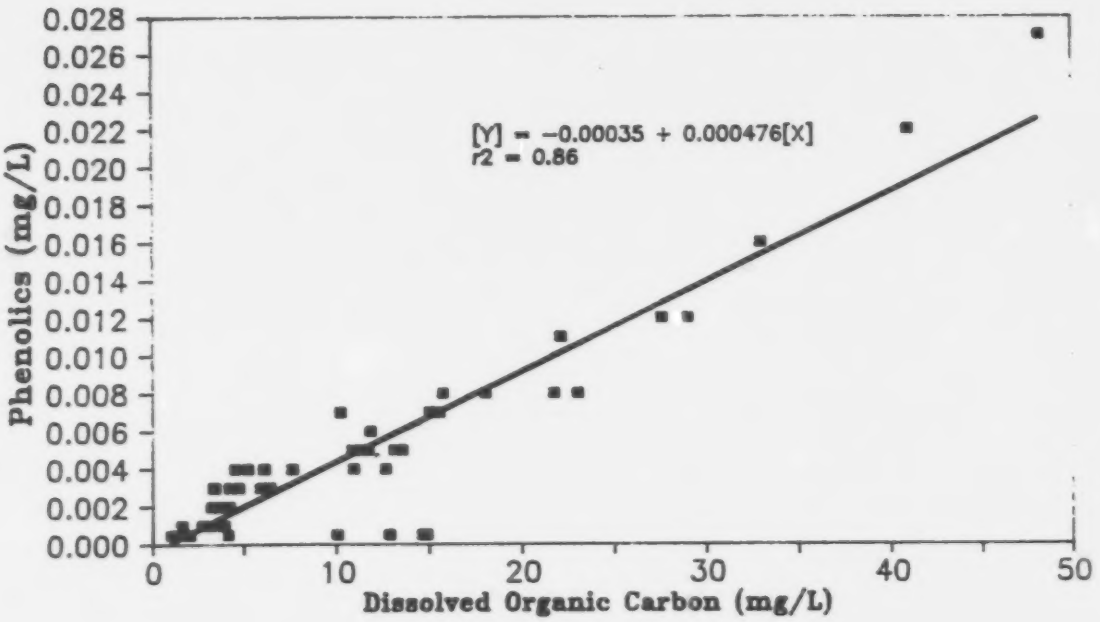
Locations	Survey:	Load - kg/d 88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)		9.0		14		23
Inputs:						
AR u/s HCE		1.1		1.4		1.6
HCE		8.3		18		2.1
2. AR d/s Whitecourt (25 km)		2.3		41	42	53
Inputs:						
AR u/s Whitecourt		6.3		15	15	20
McLeod River		0.2		0.8	0.4	0.8
MWPL effluent				51	35	38
Whitecourt STP effluent				0.0	0.0	0.0
3. AR at Athabasca				38	30	39
Inputs:						
AR u/s L. Slave River		1.9		27	22	33
Lesser Slave River		0.5		11	10	9.8
Athabasca STP effluent				0.0		0.0
4. AR d/s Ft. McMurray (near Bitumount)		31	34	44		60
Inputs:						
AR u/s Ft. McMurray (near Horse R.)		18	23	33		43
Clearwater River		9.2	11	17		16
Ft. McMurray STP effluent			0.3	0.3		0.1
Suncor process effluent			0.3	0.2		0.2

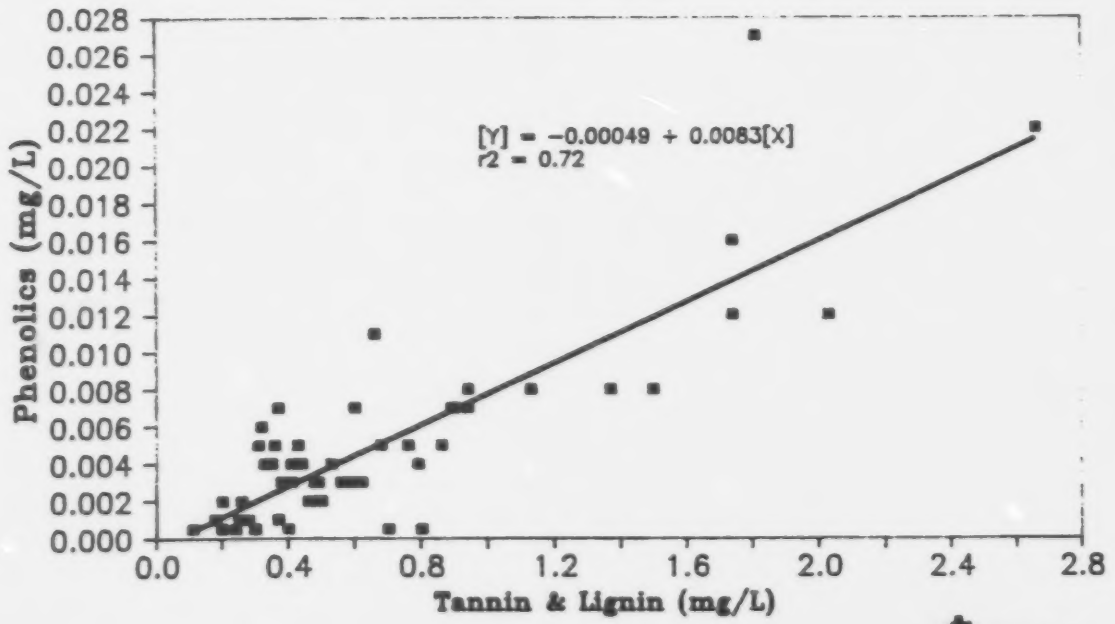
reported previously (Clayton, 1972; Hamilton et al., 1985). The relatively low phenolic concentrations in 1988, compared to 1989, may be an analytical error rather than an indication of temporal variability (Appendix 11). Phenolic concentrations declined downstream of Hinton to Whitecourt, where, in 1989 they increased markedly due to discharge from the MWPL mill (Table 12). In 1989, phenolic concentrations declined to 0.004 to 0.006 mg/L in the vicinity of the Town of Athabasca and remained near that level farther downstream (Figure 14).

Downstream of Whitecourt, phenolic concentrations in tributaries were similar to those in the Athabasca River (Appendices 1 to 5) and tributary inflow may have contributed to the phenolic concentrations in the lower half of the river. Many of these tributaries are natural 'brownwater' streams and they contain appreciable amounts of dissolved organic carbon, including tannin, lignin and phenolics. These compounds were positively correlated with one another (Figure 15). Sewage effluents and the Suncor process effluent contributed much smaller loads to the river than did the tributaries (Table 12).

Concentrations of phenolics measured in this study were within the range measured in previous winters (Figure 14). Data from previous winters will also include any effect of the HCE. The first year in which MWPL discharged effluent to the river was in 1989. Previous winter data collected immediately downstream of Whitecourt are scarce (n=2; 0.003 and 0.007 mg/L), but it is probable that phenolic concentrations were much lower immediately downstream of Whitecourt prior to 1989.

Figure 15. Relationship of phenolics to dissolved organic carbon and tannin and lignin in tributaries of the Athabasca River, winter 1988 and 1989.





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The ASWQO for phenolics is 0.005 mg/L. Concentrations in much of the Athabasca River downstream of Hinton were non-compliant with that objective during at least some portion of January to March, 1989 (Figure 14). The CWQG for phenolics is 0.001 mg/L; it was exceeded at all sites downstream of Hinton.

3.9 Tannin and Lignin

Tannin and lignin are constituents of plant matter and are ubiquitous in the environment as a result of decaying vegetation (CCREM, 1987). Lignin is the compound primarily responsible for the rigidity of wood and is not differentiated from tannin in the analytical test. Lignin is of interest because it imparts a brown colour to kraft pulp mill effluent, which is aesthetically objectionable and may reduce photosynthesis in the receiving water by reducing the transmission of light (Parker and Sibert, 1972).

During this study, concentrations of tannin and lignin upstream of Hinton ranged from 0.05 to 0.18 mg/L and increased to about 1.5 mg/L immediately downstream of Hinton (Figure 16). The increase was due to the high tannin and lignin load from the HCE (Table 13). Concentrations decreased to about 0.9 mg/L upstream of Whitecourt. Tannin and lignin loads from the MWPL effluent and Whitecourt STP were low relative to that from that from the HCE, and no sharp rise in tannin and lignin concentrations were observed downstream of these effluents. Downstream of Whitecourt, concentrations declined to approximately 0.6 mg/L at Smith, then remained relatively constant to Lake Athabasca (Figure 16). Many of the tributaries to the lower half of the river contained appreciable amounts of tannin and lignin (Appendices 1 to 5).

Figure 16. Winter Tannin and Lignin Concentrations in the Athabasca River

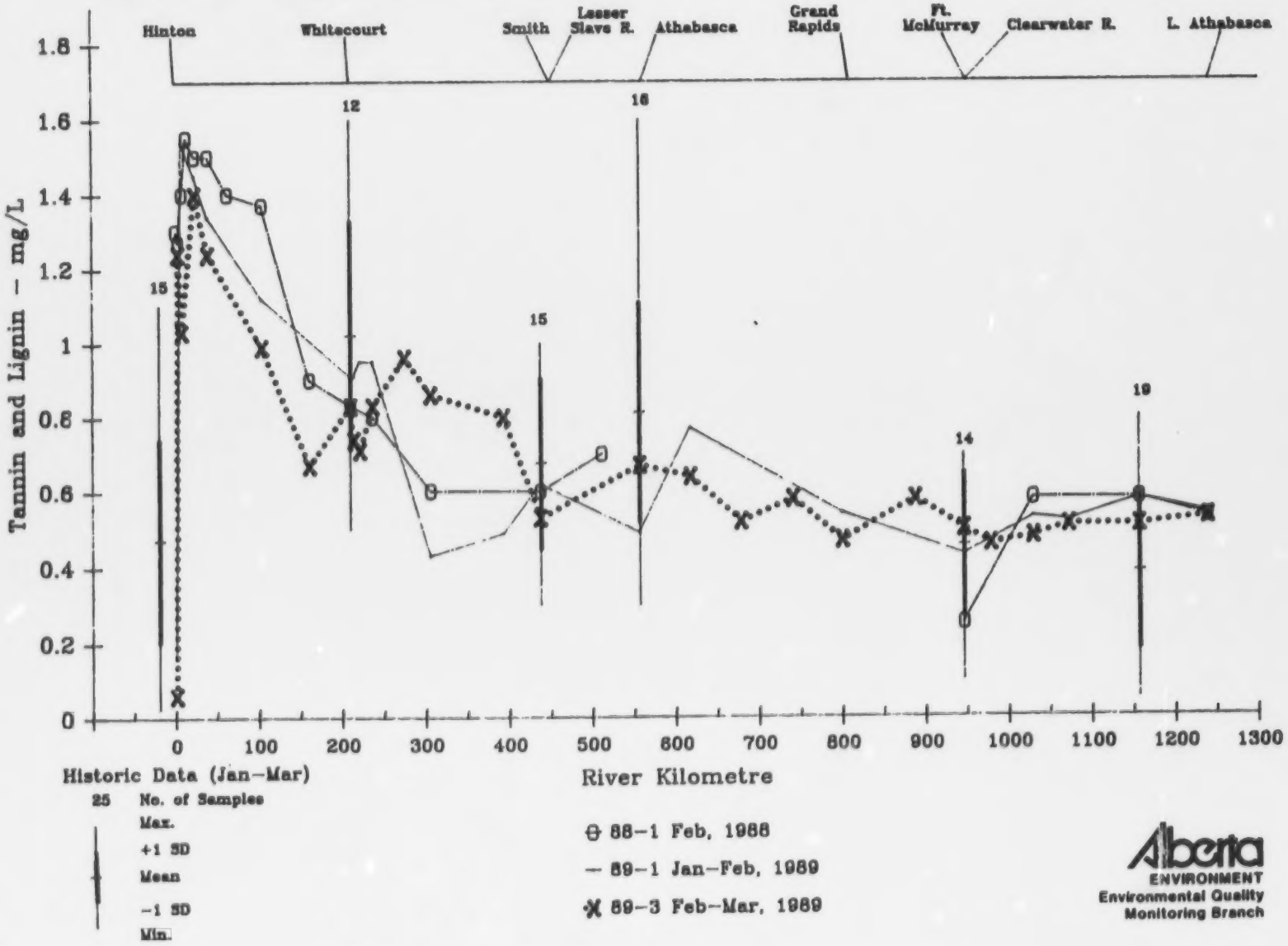


TABLE 13. Mass load of tannin and lignin at selected locations.

Locations	Load - kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	3400				3500
Inputs:					
AR u/s HCE	290		440		150
HCE	4700		4000		3400
2. AR d/s Whitecourt (25km)	3600		3900	4000	3600
Inputs:					
AR u/s Whitecourt	3500		3300	2900	3300
McLeod River	64		190	74	100
MWPL effluent			860	640	740
Whitecourt STP effluent			4.7	2.8	3.4
3. AR at Athabasca			3700	3700	4400
Inputs:					
AR u/s L. Slave River	2200		3300	3500	2500
Lesser Slave River	320		940	740	610
Athabasca STP effluent					2.0
4. AR d/s Ft. McMurray (near Bitumount)	4400	5900	5900		5700
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	1100	5000	3500		3100
Clearwater River	1200	1500	2300		1800
Ft. McMurray STP effluent		23	28		5.8
Suncor process effluent		23	17		13

Tannin and lignin concentrations measured during this study were within the range of historic data (Figure 16), but the historic data includes the influence of the HCE. There are no ASWQO or CWQG for these compounds.

3.10 Diethylenetriaminepentaacetic and Ethylenediaminetetraacetic Acid

Diethylenetriaminepentaacetic acid (DTPA) and ethylenediaminetetraacetic acid (EDTA) are chelating agents used in CTMP mills. These organic compounds are undesirable in aquatic systems because they stabilize toxic heavy metals and are persistent (Means et al., 1980). Millar Western Pulp Ltd. had projected that these organic compounds would be present in their effluent; therefore, they were analyzed in the 1989 surveys.

Concentrations of DTPA and EDTA in the Athabasca, McLeod, and Pembina rivers were below detection limits (<0.5 mg/L) at all sites and for all surveys (Table 14). DTPA and EDTA were detected in the MWPL effluent at concentrations of 31.3 to 43.6 mg/L and 10.5 to 15.6 mg/L, respectively. However, the load from MWPL was low relative to the discharge of the river, and DTPA/EDTA concentrations downstream of MWPL did not increase above the analytical detection limit of 0.5 mg/L.

There are no ASWQO or CWQG for DTPA or EDTA. Data compiled by Verschueren (1983) indicates a lowest observed effect level of 1 mg/L, above which DTPA may have an inhibitory effect on algae. There are some indications that EDTA may be more toxic than DTPA (Srivastave et al., 1986).

TABLE 14. Winter DTPA and EDTA concentrations in the Athabasca River system and Millar Western Pulp Ltd. effluent.

		DTPA - mg/L			EDTA - mg/L		
STATION	Survey:	89-1	89-2	89-3	89-1	89-2	89-3
AR u/s Whitecourt		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Mcleod River		<0.5		<0.5	<0.5		<0.5
MWPL effluent		31.3	37.8	43.5	15.6	11.0	10.5
AR 3km d/s McLeod River		<0.5		<0.5	<0.5		<0.5
AR 10km d/s McLeod River		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
AR near Blue Ridge		<0.5		<0.5	<0.5		<0.5
AR near Ft. Assiniboine		<0.5		<0.5	<0.5		<0.5
Pembina River		<0.5		<0.5	<0.5		<0.5
AR u/s Smith		<0.5		<0.5	<0.5		<0.5
AR at Town of Athabasca		<0.5			<0.5		
AR u/s Horse River		<0.5		<0.5	<0.5		<0.5

3.11 Trace Organic Compounds

This group is considered to comprise the organic compounds analyzed by gas chromatography - mass spectrometry (GC-MS). In this report, emphasis is placed on the organic non-pesticide priority pollutants as identified by the USEPA (Appendix 8). Most of these compounds are toxic to fish and humans, and many are carcinogenic and mutagenic (Moore and Ramamoorthy, 1984). The fate of these compounds in the aquatic environment is determined by a number of different processes such as sorption/desorption, volatilization, and chemical and biological transformations. Chlorinated dioxins and furans were not analyzed in these surveys. They were investigated in 1987 and around the HCE (Alberta Environment, 1988) and are under further investigation as part of Environment Canada's national dioxin survey.

A large number of trace organic compounds have been identified in pulp mill effluents; McKague et al. (1989) list 313 compounds, as of January 1989. It is reasonable to assume that many other trace organics occur in these effluents but have not yet been characterized.

Much information is available on the nature of organic compounds present in pulp mill effluent that are toxic to fish. Most of the acute toxicity is due to resin acids, fatty acids and chlorinated phenols (D. McLeay and Associates Ltd., 1987). There is relatively little information on effluents from CTMP mills, although concentrations of resin acids are expected to be higher than in effluents from kraft mills (D. McLeay and Associates Ltd., 1987), depending on the wood supply (Voss, 1983).

The quality and quantity of trace organic compounds detected in this study, particularly in the HCE, were highly variable from survey to survey (Appendix 6). Some of the differences in trace organics detected in the HCE between 1988 and 1989 may have been a result of a change in analytical laboratories from AEC in 1988 to ETL in 1989 (for effluents only, Section 2.3). However, changes in the trace organics reported for the HCE were also observed among the three 1989 surveys, all of which were analyzed by ETL, and among samples collected in previous years, which were analyzed by AEC (Appendix 9; EQMB, Alberta Environment, unpublished data).

Chloroform was the only priority pollutant detected in the Athabasca River during all four surveys (trace organics were not measured in survey 88-2). Chloroform concentrations in the river ranged from below detection limits to 4 µg/L (Table 15). Appreciable amounts of chloroform are often associated with effluent from bleached kraft mills (Bonsor et al., 1988). In the HCE, chloroform concentrations ranged from 12 to 53 µg/L. Chloroform was also detected at low concentrations (trace and 2 µg/L) in two blank samples analyzed by AEC in 1989. Therefore, some values measured for the river may have been an artifact of sampling and/or laboratory errors. Even so, the HCE probably had an impact on downstream chloroform concentrations because: (1) chloroform was not detected upstream of Hinton, (2) in general, the highest concentrations in the river were recorded in the reach between Hinton and Whitecourt (Table 15), and (3) a similar pattern was observed during February 1985, in a previous study of trace organics near Hinton (EQMB, Alberta Environment, unpublished data).

TABLE 15. Trace organic priority pollutants in the Athabasca River and selected effluents, winter 1988 and 1989.

COMPOUND	AR u/s Hinton	HCE	AR 21km d/s Hinton	AR 36km d/s Hinton	AR u/s Berland River	AR u/s White-court	MAPLE	White-court STP	AR 10km d/s McLeod	AR at Blue Ridge	AR at Fort Assin.	AR u/s Smith	AR at Atha-basca	AR at McMillan Lake	AR u/s Horse River	Suncor effluent	AR at Old Fort
SURVEY 88-1:																	
Chloroform	-	12	-		-	1.X						-	-				
SURVEY 89-1:																	
2,4,6-Trichlorophenol	-	20	-	-	-	0.X	-		-	-	-	-	-	-	-	-	-
Hexadecanoic acid	-	-	-	1.X	-	1.X	125		-	-	-	-	-	1.X	1.X	-	2.X
1,2-Dichloroethane	0.X	<5	-	0.X	0.X	0.X	-		0.X	0.X	-	-	-	-	-	-	-
Chloroform	-	53	4	3	2	1	-		1.X	1.X	1.X	1.X	1.X	0.X	0.X	2	-
Ethylbenzene	-	-	-	-	-	-	-		0.X	-	-	-	-	-	-	-	-
m,p-Xylene	-	-	-	-	-	-	-		-	0.X	-	-	-	-	-	-	-
Toluene	-	7	0.X	-	-	-	-		-	0.X	-	-	-	-	-	-	-
SURVEY 89-2:																	
2.4.6-Trichlorophenol						0.X	-				1.X	-					
Hexadecanoic acid						1.X	-				1.X	1.X					
Chloroform						1.X	-				-	0.X					
SURVEY 89-3:																	
2,4,6-Trichlorophenol	-	12	-	0.X	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexadecanoic acid	-	-	2.X	-	2.X	2.X	10	10	2	1.X	1.X	-	-	-	-	-	-
Chloroform	-	46	-	2	-	-	1	2	1.X	1.X	1.X	1.X	-	-	0.X	1	0.X

Values are in µg/L. Only compounds detected in the river are listed; blank - no sample; dash - compound analyzed but not detected. Detection limits in Appendix 8.
X estimated value; B possible contamination.

For Survey 88-1: chloroform at 6km d/s Hinton was 1.X µg/L.

Chloroform is of concern because it is slightly toxic and a presumed carcinogen (Bonsor et al., 1988). However, it does not appear to be an important hazard for aquatic ecosystems because it is volatile, and the potential for bioaccumulation and sorption is low (USEPA, 1979). River ice-cover would restrict removal of chloroform by volatilization. Even so, high concentrations of chloroform were not observed downstream of the HCE.

There are no ASWQO or CWQG for chloroform. However, there are CWQG for raw drinking water for trihalomethanes, a group of halogen-substituted single carbon compounds that includes chloroform. The CWQG allows a maximum acceptable concentration of 350 µg/L; about 100 times the concentration of chloroform measured in the Athabasca River during this study.

Two priority pollutants were detected in river samples in all three surveys in 1989, but not in 1988: hexadecanoic acid, and 2,4,6-trichlorophenol. Hexadecanoic (palmitic) acid is a fatty acid. Concentrations in river samples ranged from below detection limits to 2 µg/L (Table 15). A concentration of 1 µg/L was recorded in one of two blank samples submitted to AEC in 1989 (Appendix 11); thus, at least some of the observed river values may be an artifact of sample contamination or analytical errors. High concentrations of hexadecanoic acid have been measured in pulp mill effluents (CCREM, 1987). In the HCE, hexadecanoic acid was not detected; in the MWPLE, concentrations ranged from below detection limits to 125 µg/L (Table 15). However, there were no observed increases in concentrations in the Athabasca River immediately downstream of the MWPLE. Previous water quality

investigations did not detect hexadecanoic acid in the Athabasca River (EQMB, Alberta Environment, unpublished data). There are no ASWQO or CWQG for this compound.

During the winter surveys, concentrations of 2,4,6-trichlorophenol in the Athabasca River ranged from below detection to 1 µg/L (Table 15). This chlorinated phenolic compound is often present in kraft pulp mill effluents (CCREM, 1987); concentrations in the HCE ranged from below detection limits to 20 µg/L. Biodegradation is the primary mechanism for removal of chlorinated phenols from surface waters (CCREM, 1987). In two previous studies on the Athabasca River, 2,4,6-trichlorophenol was not detected (EQMB, unpublished data). There are no ASWQO for this compound. The CWQG is 18 µg/L, based on acute toxicity to aquatic organisms and was not exceeded at any sites in the Athabasca River during this study.

Four priority pollutants were detected in the river at trace levels (<0.5µg/L) during survey 89-1: 1,2-dichloroethane, ethylbenzene, m,p-xylene, and toluene (Table 15). Dichloroethane was detected at several sites, including upstream of Hinton, and the pattern suggests a systematic sample contamination problem, rather than a real occurrence. Ethylbenzene and m,p-xylene were only detected at one site and further sampling would be necessary to confirm their presence. Toluene was present in the HCE and at two downstream sites, indicating the effluent may have affected concentrations in the river water (Table 15). The observed concentrations of toluene in the river were much lower than the CWQG of 300µg/L (CCREM, 1987).

In addition to the priority pollutants, a number of other trace organic compounds were tentatively identified; the ones that were persistent (detected at three or more consecutive sites in any one survey) or detected at relatively high concentrations (>5 µg/L) are listed in Appendix 6 and summarized in Table 16. It appears that the HCE was the source for many of these compounds because (1) these compounds were not detected upstream of Hinton, (2) they tended to be most persistent and/or their highest concentrations were recorded in the reach from Hinton to Whitecourt, and (3) many of these compounds were detected in the HCE and/or are known to occur in pulp mill effluents (D. McLeay and Associates Ltd., 1987; McKague et al., 1989).

3.12 Organic Carbon

Carbon is the most abundant element found in all organisms. Organic carbon makes up about 10% of total carbon in lakes and rivers (CCREM, 1987). Organic carbon in surface waters is derived from watershed runoff, anthropogenic inputs and instream river production (e.g., photosynthesis). Effluents from pulp mills and sewage treatment plants often have high organic carbon concentrations (McNeely et al., 1979).

Total organic carbon (TOC) includes both the dissolved and particulate (>0.45 µm) organic carbon fractions. For this study, TOC was only measured during survey 88-1, and dissolved organic carbon (DOC) was measured during all surveys. For survey 88-1, most of the TOC in the Athabasca River (70%) and the HCE (80%) was in the dissolved fraction (Appendix 1).

TABLE 16. Tentatively identified trace organic compounds detected at concentrations ≥ 5µg/L and/or at three or more sites along the Athabasca River, winter 1988 and 1989.

COMPOUND	CONCENTRATION µg/L	SURVEY
RESIN ACIDS		
Sandaracopimaric acid	5 - 50	88-1
FATTY ACIDS		
Tetradecanoic acid	0.X	89-1
PHENOLS		
Acetosyringol	0.1 - 50	88-1
Guaiacol	0.1 - 5	88-1
Tetrachloroguaiacol	0.X - 1.X	89-1, 89-3
Trichloroguaiacol	0.X - 1.X	89-1, 89-2, 89-3
Vanillin	0.X	89-1
BASE/NEUTRALS		
p-Cymen-8-ol	5 - 50	88-1
1,1-Dichlorodimethyl sulphone	0.1 - 5	88-1
1,1-Dichlorodimethyl sulphone	0.X - 3.X	89-1, 89-2, 89-3
Dichloroethane	0.X	89-1
Dimethylcyclohexane	0.X - 1.X	89-3
Dimethylcyclopentenones	0.X	89-1
Dimethyldisulphide	2.X	89-3
Fenchone	5 - 50	88-1
Limonene	0.1 - 50	88-1
Manool	0.1 - 0.5	88-1
Methylethyl thiophene	0.1 - 5	88-1
1-Methyl-4-(1-methylethyl)-benzene	0.1 - 5	88-1

Concentrations in 1988 reported as a range, in 1989 they were estimated, as indicated by the X.

In both years of the study, DOC was approximately 0.5 mg/L in the Athabasca River upstream of Hinton. Downstream of Hinton, DOC concentrations increased to about 3 mg/L due to loading from the HCE (Figure 17, Table 17). Concentrations increased an additional 1 mg/L downstream of Whitecourt due to loading from the McLeod River (1988 and 1989) and the MWPL effluent (1989). From Whitecourt to the Town of Athabasca, DOC concentrations increased due to loadings from the DOC-rich Pembina and Lesser Slave rivers (10-15 mg/L: Appendices 1 to 5). Dissolved organic carbon concentrations remained relatively constant, at 6 to 8 mg/L, downstream of the Town of Athabasca.

Concentrations of DOC in the Athabasca River during this study were generally within the range reported for previous winters (Figure 17). There are no ASWQO or CWQG for total or dissolved organic carbon.

3.13 Total Dissolved Organic Compounds

The dissolved organic constituents analyzed in this study are summarized in Table 18 for selected sampling sites. Total dissolved organic compounds (TDOC) were estimated by expressing DOC as an equivalent total organic weight; DOC was assumed to have a stochiometry of carbohydrate, e.g., C:2H:O.

In the Athabasca River, trace organics and phenols accounted for less than 0.2% of TDOC. Upstream of Hinton, tannin and lignin accounted for 8% of the TDOC. The proportion of tannin and lignin increased downstream of Hinton to 23% due to the high load of tannin and lignin from the HCE (Table 13). In the lower reaches of the river tannin and lignin accounted for less than 5% of the TDOC. The identity of the

Figure 17. Winter Dissolved Organic Carbon Concentrations in the Athabasca River

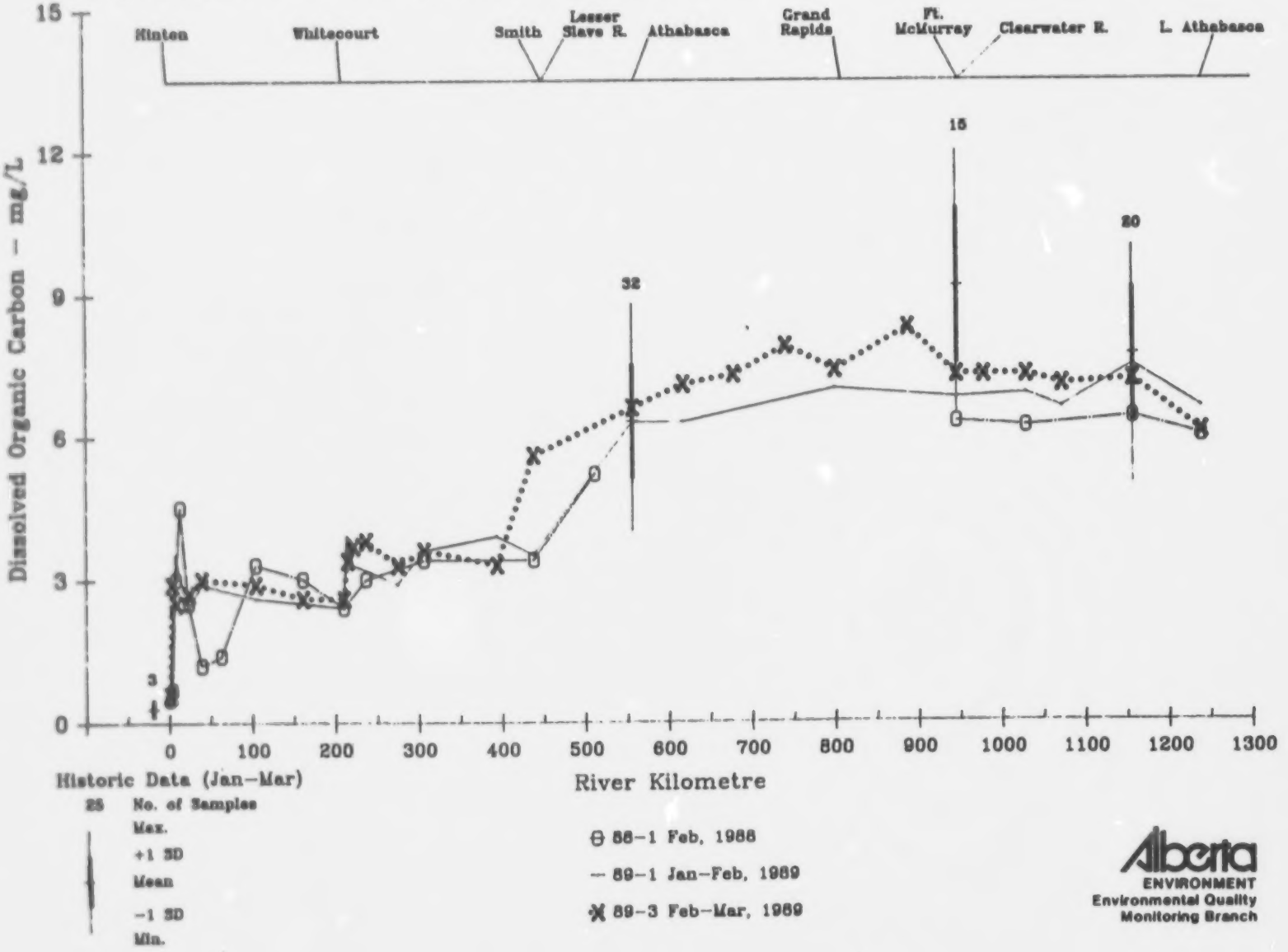


TABLE 17. Mass load of dissolved organic carbon at selected locations.

Locations	Load - 1000 kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	5.7		6.7		6.8
Inputs:					
AR u/s HCE	1.1		1.1		1.5
HCE	9.7		8.9		7.8
2. AR d/s Whitecourt (25km)	14			14	17
Inputs:					
AR u/s Whitecourt	10		8.7	9.7	10
McLeod River	1.3		1.6	1.4	1.3
MWPL effluent			6.4	4.1	6.2
Whitecourt STP effluent			0.0	0.0	0.0
3. AR at Athabasca			48	33	43
Inputs:					
AR u/s L. Slave River	13		19	19	26
Lesser Slave River	11		25	23	21
Athabasca STP effluent					0.0
4. AR d/s Ft. McMurray (near Bitumount)	47	67	76		87
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	29	51	49		45
Clearwater River	14	15	26		24
Ft. McMurray STP effluent		0.3	0.5		0.1
Suncor process effluent		0.2	0.2		0.2

TABLE 18. Dissolved organic compounds at selected sites in the Athabasca River system, winter 1988 and 1989.

SITE	PHENOLIC COMPOUNDS	TANNIN AND LIGNIN	TRACE ORGANIC COMPOUNDS	DOC as CARBO-HYDRATE
AR u/s Hinton	0.001	0.12	<0.001	1.5
HCE	0.11	48.3	1.59	263
AR 21km d/s Hinton	0.006	1.45	0.007	6.4
AR u/s Whitecourt	0.004	1.05	0.003	6.3
MWPLE	3.57	64.3	3.09	1205
AR at Blue Ridge	0.008	0.88	0.002	8.5
AR at Town of Athabasca	0.005	0.59	<0.001	15.3
AR u/s Ft. McMurray	0.005	0.49	0.001	17.1
AR d/s Ft. McMurray	0.004	0.53	<0.001	16.5

Values in mg/L, mean of all surveys where data were collected.

remaining organic constituents is not known; but, they could include proteins, carbohydrates, fats, resin acids and, especially in the river samples, humic and fulvic acids (Wetzel, 1983; D. McLeay and Associates, 1987).

3.14 Colour

True colour is the colour of a filtered water sample and results from materials dissolved in the water. True colour can be imparted to water by inorganic compounds such as iron and colloidal $CaCO_3$ and by dissolved organic matter such as humic acids, tannin, and lignin (Wetzel 1983). True colour was measured in all surveys except 88-1. In that survey, apparent colour was measured in samples from the upper Athabasca River. Apparent colour is the colour of an unfiltered sample, which includes both dissolved and suspended material and their influences on colour.

In the Athabasca River upstream of Hinton, true colour ranged from 1 to 5 relative units (RU). True colour increased to about 50 RU immediately downstream of Hinton (Figure 18) due to discharge of the HCE (Table 19). By Whitecourt, colour in the river water had declined to about 30 RU. Downstream of Whitecourt, concentrations were relatively constant at about 20 RU.

The largest point load of true colour to the Athabasca River was from the HCE (1,000 to 2,500 RU). The colour load from the HCE was 8 to 79 times greater than the colour load in the Athabasca River upstream of Hinton (Table 19). Colour was also high in the MWPLE (320 to 750 RU). However, the colour load was only about 5 % of that in the Athabasca River upstream of Whitecourt, and it had little impact on the colour of river water (Figure 18).

Figure 18. Winter True Colour in the Athabasca River

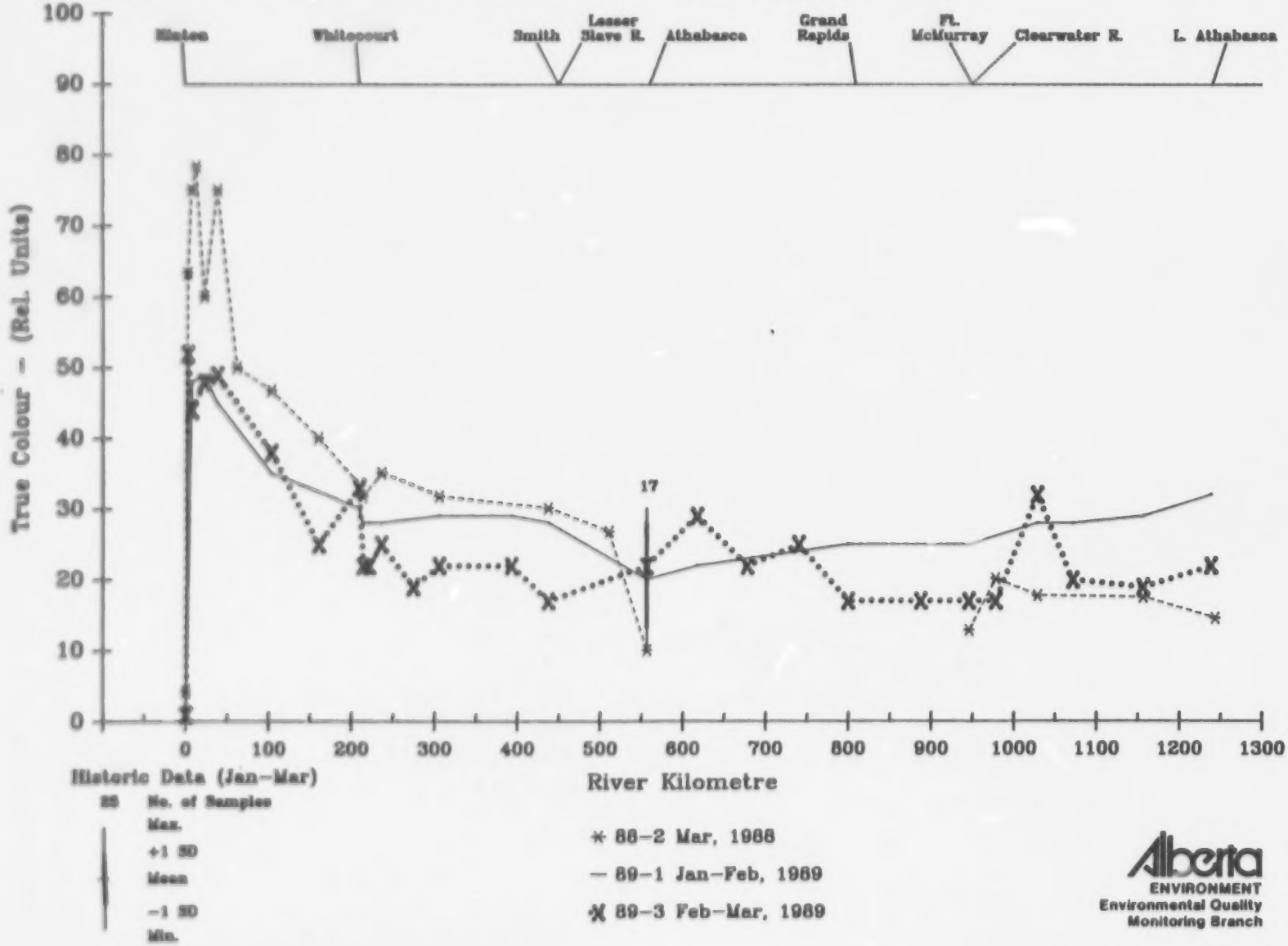


TABLE 19. Mass load of true colour at selected locations.

Locations	Load - 1000 pseudo kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)		170	140		120
Inputs:					
AR u/s HCE		11	2.7		2.4
HCE	200	84	110		190
2. AR d/s Whitecourt (25km)		180	110	120	110
Inputs:					
AR u/s Whitecourt		150	110	120	130
McLeod River		6.5	3.7	3.7	1.6
MWPL effluent			4.9	3.8	8.0
Whitecourt STP effluent			0.1	0.1	0.1
3. AR at Athabasca		63	150	160	140
Inputs:					
AR u/s L. Slave River		[illegible]	150	130	79
Lesser Slave River		22	44	43	28
Athabasca STP effluent					0.1
4. AR d/s Ft. McMurray (near Bitumount)	170	200	310		380
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	110	97	160		106
Clearwater River	65	34	150		88
Ft. McMurray STP effluent		0.5	0.8		0.2
Suncor process effluent		0.5	0.5		0.3

Pseudo-kg/d calculated by expressing relative colour units as mg/L.

In addition to pulp mill effluent, tributaries are a source of colour to the Athabasca River. In the tributaries, colour ranged from 1 to 174 relative units. The highest values were for tributaries between Athabasca and Bitumount (Appendices 1 to 5). The colour of the tributaries was positively correlated ($P < 0.05$) to concentrations of naturally occurring solutes that are known to impart colour to water, i.e., DOC, and tannin and lignin, and iron (Figure 19); true colour was most strongly correlated with tannin and lignin.

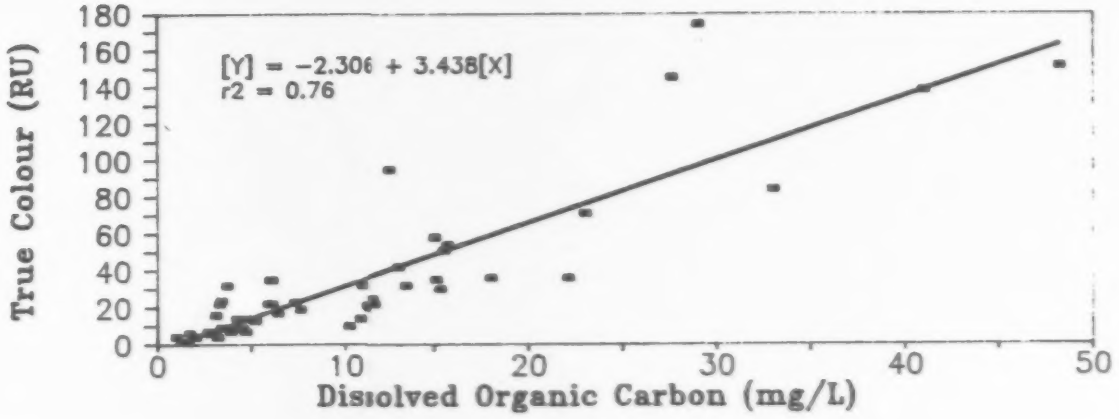
There are few true colour data for the Athabasca River from previous winters. Values of true colour that were measured during this study were within the range of historic data (Figure 18).

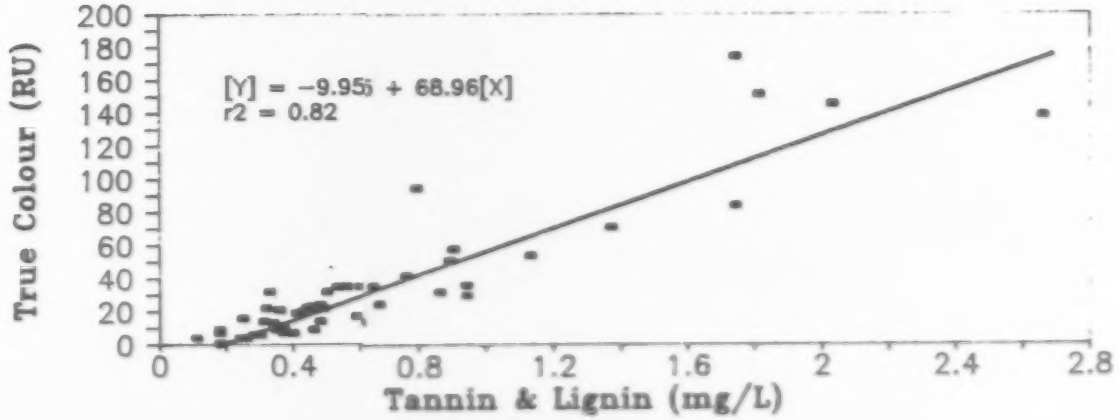
The ASWQO allows a maximum increase of 30 units with respect to background values; the reach between Hinton and Whitecourt was non-compliant with that objective, as compared to the river upstream of Hinton. Colour affects the aesthetic quality of water for drinking and recreational use. The latter would be limited in winter, but occurs on the river at other times of the year. High levels of colour reduces light penetration, thereby limiting aquatic photosynthesis. However, the effect of colour on photosynthesis has not been evaluated for the Athabasca River.

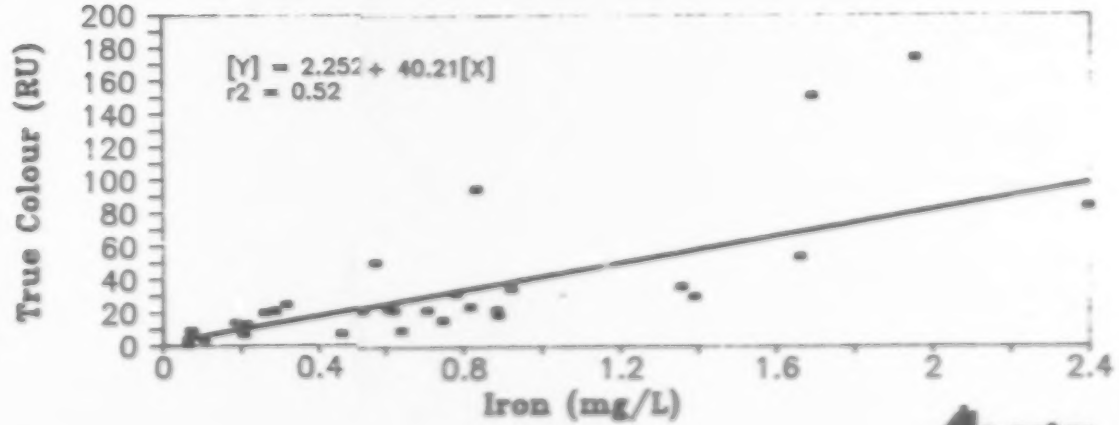
3.15 Odour

Odour in water may result from a wide range of volatile compounds. Kraft pulp mill odours are usually a result of reduced sulfur compounds, which are present in air and water emissions. Such compounds have been detected in the Athabasca River from downstream of Hinton to near Whitecourt (EQMB, Alberta Environment, unpublished data).

Figure 19. Relationship of true colour to dissolved organic carbon, tannin and lignin, and iron in tributaries of the Athabasca River, winter 1988 and 1989.







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Odour was evaluated with respect to its intensity and nature by field crews on site. Field evaluation was used rather than laboratory analysis of "threshold odour number" (the lab threshold odour test also uses olfactory evaluation of sample water). Previous surveys showed that the routine lab analysis could not always detect odour that was clearly present in river water (EQMB, Alberta Environment, unpublished data). The field odour evaluations are subjective but were corroborated by other crew members, by the project manager, and by blind tests at the field base on sufficient occasions to establish confidence in the evaluations.

Odour data are compiled in Table 20. On all occasions, no odour was detected in the Athabasca River upstream of Hinton. In the first few kilometres downstream of Hinton, odour was always present and was described by the field crews as 'pulp mill-like' (i.e., kraft pulp mill). Odour generally declined progressively downstream of Hinton. The rate of decline varied between surveys with odour appearing to be the most persistent in Survey 89-3. This may reflect the more complete ice cover that was present during that survey compared to previous surveys, and which would reduce volatilization of odourous compounds.

In 1988, odour in river water persisted to the vicinity of Smith. In March 1989, odour persisted to the lower-most reaches of the Athabasca River where field crews rated the odour as 'high' (Table 20). Particular care was taken to confirm the 1989 evaluations in view of the degree of persistence downstream. The nature of the odour was clearly 'pulp mill-like' down to about Smith in both years. Downstream of the Smith to Athabasca reach, the odour was usually more non-descript,

TABLE 20. Field evaluations of odour at selected sites in the Athabasca River system

	1988		1989		
	1-11 Feb	4-9 March	9 Jan - 15 Feb	26 Jan - 6 Feb	13 Feb - 16 March
AR u/s Hinton	Nil	Nil	Nil	-	Nil
AR 6 km d/s HCE	++	++	+	-	+++
AR 36 km d/s HCE	+	++	+	-	+++
AR u/s Berland R.	+	++	+	-	+++
Berland R.	Nil	Nil	Nil	-	Nil
AR u/s Whitecourt	+	+	+	+++	++
McLeod R.	Nil	Nil	Nil	Nil	Nil
AR 3 km d/s McLeod R.	+	++	+	+++	+++
AR at Blue Ridge Br.	+	++	+	++	+++
AR at Ft. Assiniboine	+	+	++	++	+++
Pembina R.	Nil	Nil	Nil	-	Nil
AR u/s Smith	+	+	+	++	+++
Lesser Slave R.	Nil	Nil	Nil	+	Nil
AR at Athabasca	Nil	Nil	Nil	+	+
AR u/s La Biche R.	-	-	+	-	+++
La Biche R.	-	-	+	-	Nil
AR u/s House R.	-	-	+	-	++
AR u/s Ft. McMurray	-	-	+	-	++
Clearwater R.	-	-	Nil	-	Nil
Mackay R.	-	-	Nil	-	Nil
AR near Bitumount	-	-	+	-	++
Firebag R.	-	-	Nil	-	Nil
AR at Old Fort	-	-	+	-	+++
AR at mouth	Nil (20 Jan)	-	+	-	+++

AR Athabasca River, u/s upstream, d/s downstream,
HCE Hinton combined effluent, dash (-) not determined.

Odour intensity (relative to most surface waters):

+++ = High (strong or quite distinct)
++ = Medium (definitely noticeable)
+ = Low (faint, but present)
Nil = no discernible odour

sometimes resembling kraft mill odours and sometimes described by field crews as 'chemical-like' or 'sewage-like'. In the tributaries, faint odours were detected only on three occasions. These were described as 'musty' or 'swampy' and were different in nature from the odour in the Athabasca River.

In the Athabasca River system, the HCE was clearly the most odourous effluent, and it had the highest effluent discharge rate to the Athabasca River (Table 3). It has long been recognized to impart considerable odour to the river (Clayton, 1972). The MWPL effluent is much less odourous and did not appear to affect river odour (Table 20). Similarly, none of the other individual effluents appeared to cause any notable or consistent increase in river odour although, in total, they may have had some effect.

Odour in water may affect its suitability for use as municipal supply, although to date this does not appear to have been a problem on the Athabasca River system. Local domestic use of river water occurs in the lower Athabasca River and Delta and could be affected by odour. There have been complaints from that area about odour in the past, although complainants have attributed the problem to the oil sands industry. Odour may affect recreational use, although when odour is most persistent (i.e., winter) recreational use of the river is likely very low. In the open water season, odour may impair recreational capability in the reach of river downstream of Hinton. Odour itself likely does not affect aquatic life, but the compounds that produce odour may also taint fish.

3.16 Nitrogen

Nitrogen is a nutrient that can limit the growth of aquatic algae and macrophytes. Concentrations of nitrogen in aquatic systems are highly variable. Nitrogen in aquatic systems occurs in various inorganic forms, e.g., dissolved molecular nitrogen (N_2), nitrite (NO_2^-), nitrate (NO_3), ammonium (NH_4^+), ammonia (NH_3), and various organic compounds (e.g., amino acids, amines, proteins). These forms are linked together in the aquatic nitrogen cycle through the process of ammonification, nitrification and dentrification.

3.16.1 Inorganic Nitrogen

Nitrite (NO_2^-) is an intermediate, partly oxidized ion; it is usually scarce in surface waters because it is rapidly oxidized to the more stable nitrate ion. Nitrite is toxic to fish, but it is usually scarce in uncontaminated surface water; its presence in aquatic systems is usually a result of industrial effluents (CCREM, 1987).

During this study, concentrations of NO_2^--N in the Athabasca River were low, ranging from 0.001 to 0.006 mg/L (Appendices 1 to 5). Concentrations of NO_2-N in the tributaries were similar to those in the Athabasca River, while concentrations in the effluents ranged from <0.003 mg/L (HCE, Survey 88-1) to 0.76 mg/L (Whitecourt STP, Survey 89-2). However, there were no apparent increases in NO_2^--N concentrations in the river due to loading from effluents (Appendices 1 to 5). Nitrate concentrations in the Athabasca River during this study were within the range reported for previous winters (1980-1987; <0.001 to 0.017 mg/L). The maximum NO_2^--N concentration detected in the river (0.006 mg/L) was well below the ASWQO and CWQG of 0.06 mg/L.

Nitrate (NO_3^-) is the stable, oxidized nitrogen ion; it is more abundant than nitrite in natural waters. Nitrate is assimilated into organic nitrogen compounds by autotrophic organisms. During laboratory analysis, NO_3^- is reduced to NO_2^-; thus it is reported as nitrate+nitrite-nitrogen (NO_3^-+NO_2^-).

Concentrations of NO_3^-+NO_2^--N in the Athabasca River ranged from 0.055 mg/L upstream of Whitecourt to 0.206 mg/L at the mouth of Goose Island Channel (Figure 20). The average concentration in the Athabasca River for the five surveys was approximately 0.120 mg/L. About 99% of the NO_3^-+NO_2^--N fraction was made up of NO_3^--N. Concentrations of NO_3^-+NO_2^--N increased from Hinton to Lake Athabasca; however, the concentrations at any one site varied from survey to survey. The increases in NO_3^-+NO_2^--N along the river were a result of tributary loading (Table 21). There are few NO_3^-+NO_2^--N concentrations reported for previous winters; most data were from a site at the Town of Athabasca. For that site, concentrations measured during this study were within the historic range (Figure 20). There is no ASWQO for nitrate. The CWQG for fresh water aquatic life states that "concentrations that stimulate prolific weed growth should be avoided", (CCREM, 1987). Macrophyte growth is minimal during winter, so this guideline is better evaluated for summer months.

Ammonium (NH_4^+) is generated by heterotrophic bacteria as the primary nitrogenous end product of decomposition of nitrogenous organic compounds (Wetzel, 1983). Ammonium is the reduced nitrogen ion and is readily assimilated by macrophytes. In aquatic systems, free ammonia (NH_3) is toxic to aquatic life but is generally scarce. The

Figure 20. Winter Nitrate–Nitrite Concentrations in the Athabasca River

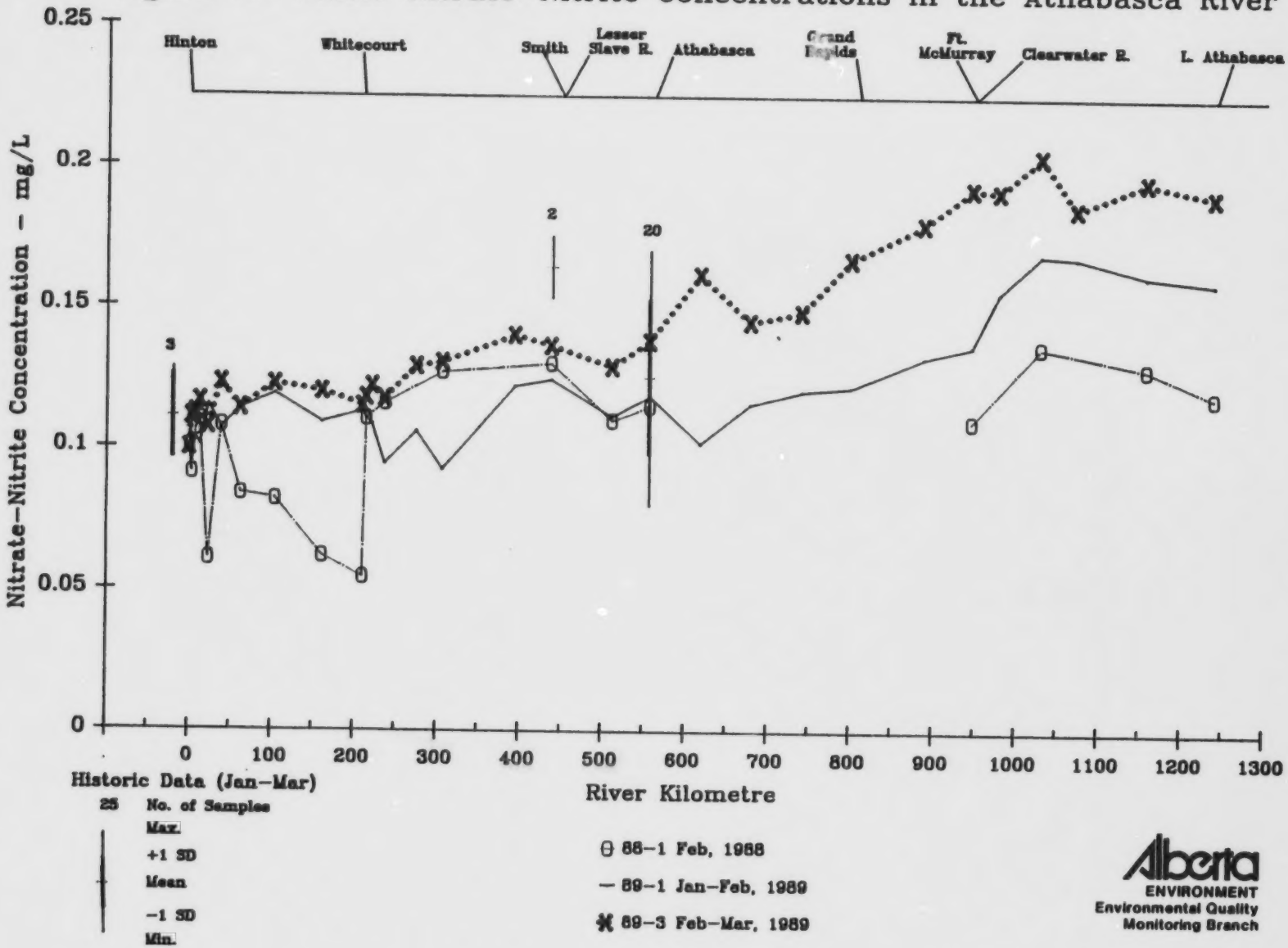

TABLE 21. Mass load of nitrate-nitrite nitrogen at selected locations.

Locations	Load - kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	140	200	310		270
Inputs:					
AR u/s HCE	220	180	280		240
HCE	0.1	7.1	4.2		0.4
2. AR d/s Whitecourt (25km)	520	590	390	420	510
Inputs:					
AR u/s Whitecourt	230	420	410	360	450
McLeod River	55	170	54	64	79
MWPL effluent			1.2	0.8	0.2
Whitecourt STP effluent			5.1	8.5	22
3. AR at Athabasca	550	1100	890	650	900
Inputs:					
AR u/s L. Slave River	480	650	670	540	630
Lesser Slave River	21	37	130	170	180
Athabasca STP effluent					0.2
4. AR d/s Ft. McMurray (near Bitumount)	1000	2200	1900		2400
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	500	1100	900		1200
Clearwater River	400	700	650		680
Ft. McMurray STP effluent			19		31
Suncor process effluent			4.2		3.5

analytical method for ammonia detects both NH_3 and NH_4^+ and reports a total $NH_3+NH_4^+$-N. The partitioning of reduced nitrogen ions between NH_4^+ and NH_3 depends on temperature and pH. The proportion of NH_3 increases with temperature, and NH_4^+ is predominant below a pH of 9 (Stumm and Morgan, 1981). In the Athabasca River and its effluents, pH was generally below 8. Thus, NH_4^+ was the dominant form in the Athabasca River system.

Concentrations of NH_4^+-N in the Athabasca River ranged from about 0.01 mg/L to 0.08 mg/L (Figure 21). The most notable feature of NH_4^+-N concentrations in the river is the sharp increase at Ft. McMurray, due to loading primarily from the Clearwater River and secondarily from the Ft. McMurray STP (Table 22). Smaller increases in NH_4^+-N concentrations were observed downstream of Hinton and Whitecourt, largely due to loading from the HCE and McLeod River, respectively (Table 22). Ammonium concentrations measured during this study were within the range reported from previous years (Figure 21).

There are no ASWQO for ammonia or ammonium. The CWQG for "total ammonia" is 1.53 mg/L for water of pH 8.0 at 0°C, conditions similar to the Athabasca River during this study. All NH_4^+ concentrations measured in the Athabasca River during this study complied with this guideline.

Figure 21. Winter Ammonium Concentrations in the Athabasca River

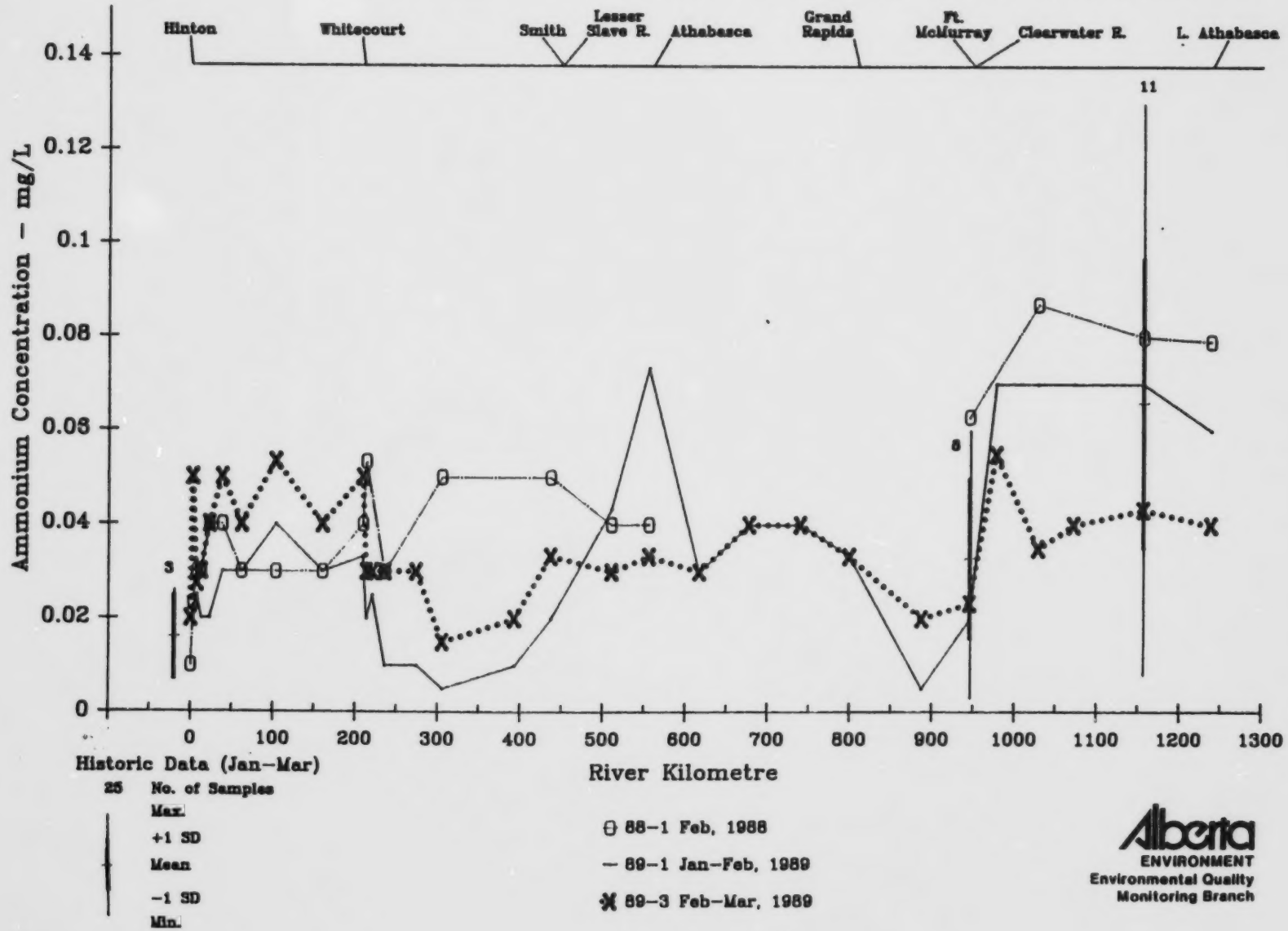

TABLE 22. Mass load of ammonium nitrogen at selected locations.

Locations	Load - kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	90	28	56		100
Inputs:					
AR u/s HCE	22	14	54		48
HCE	200	24	4.2		72
2. AR d/s Whitecourt (25km)	140	200	41	84	130
Inputs:					
AR u/s Whitecourt	170	210	120	74	200
McLeod River	21	21	41	49	48
MWPL effluent			1.1	7.3	0.9
Whitecourt STP effluent			24	21	4.7
3. AR at Athabasca	190	810	550	120	220
Inputs:					
AR u/s L. Slave River	190	100	110	150	150
Lesser Slave River	21	76	150	100	9.8
Athabasca STP effluent					20
4. AR d/s Ft. McMurray (near Bitumount)	670	1000	770		420
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	290	310	130		140
Clearwater River	350	300	300		240
Ft. McMurray STP effluent			350		83
Suncor process effluent			3.0		1.5

3.16.2 Organic Nitrogen

Organic nitrogen is determined as total Kjeldahl nitrogen (TKN) minus NH_4^+-N. The average TKN concentration along the entire length of the Athabasca River for four surveys was about 0.370 mg/L; that concentration was about several times the average NH_4^+-N concentration. As in most aquatic systems, TKN in the Athabasca River was predominantly organic nitrogen.

Organic nitrogen concentrations were approximately 0.3 to 0.4 mg/L in most of the Athabasca River (Figure 22). However, two high TKN values were measured, 5.6 mg/L upstream of Grand Rapids (Survey 89-1; Figure 22) and 4.3 mg/L upstream the Pembina River (Survey 89-2; Appendix 4). The reason for these high values is not clear. They may have been a result of particulate matter inadvertently collected in the water samples, although organic nitrogen concentrations generally increased below Hinton as a result of loading from the HCE (Table 23). In 1989, organic nitrogen also increased slightly below Whitecourt, primarily due to loading from the MWPLE. The largest point loads of organic nitrogen to the Athabasca River were from the Lesser Slave and Clearwater rivers.

For the Athabasca River, there are few records of organic nitrogen for previous winters (1980-1987: n=8, range 0.024-0.287 mg/L). Concentrations measured during this study were, in general, higher than the historic values (Figure 22). There are no ASWQO or CWQG for organic nitrogen.

Figure 22. Winter Organic Nitrogen Concentrations in the Athabasca River

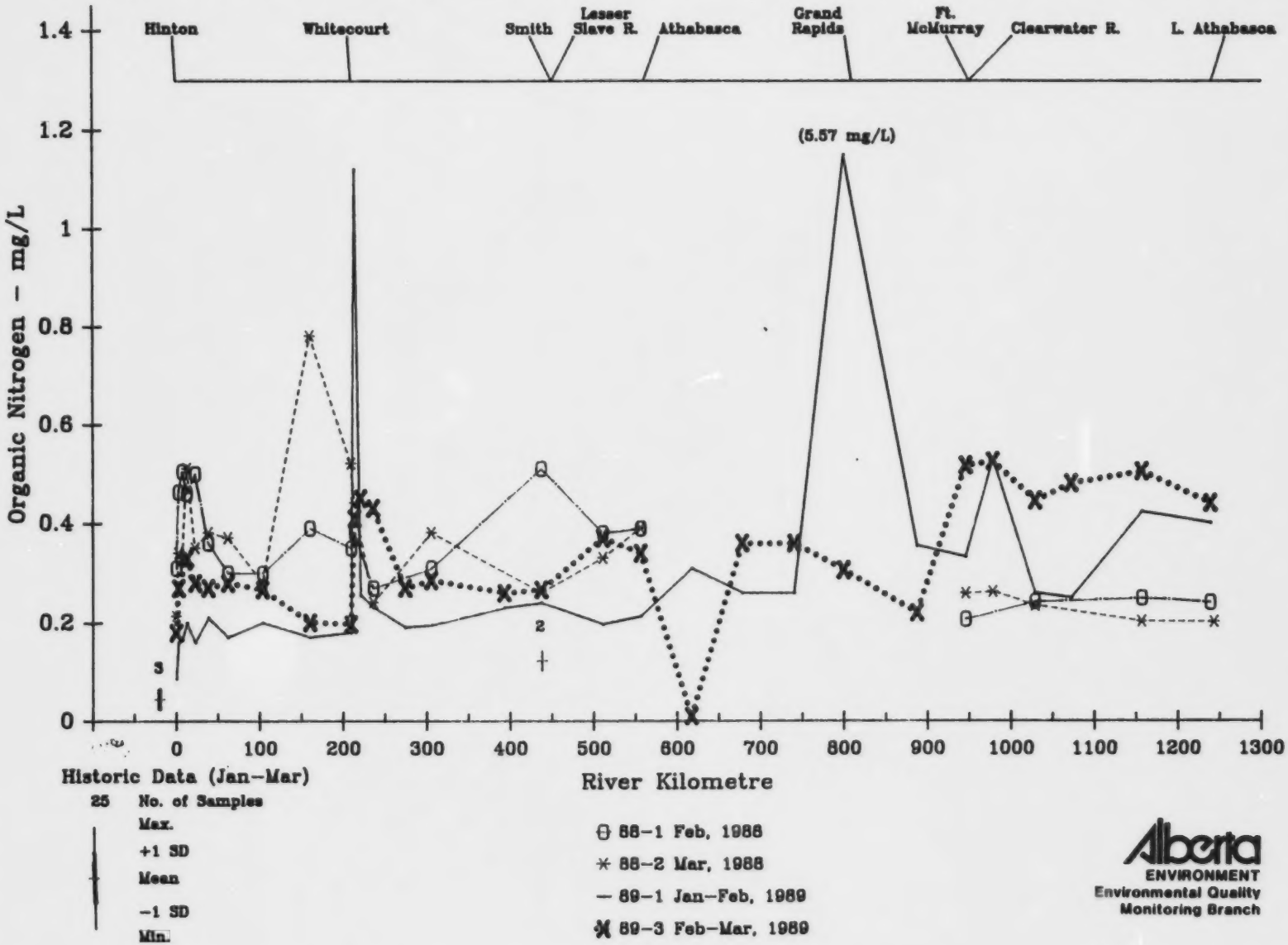

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TABLE 23. Mass load of organic nitrogen at selected locations.

Locations	Load - kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	1100	980	450		700
Inputs:					
AR u/s HCE	670	580	230		440
HCE	400	520	230		260
2. AR d/s Whitecourt (25km)	1200	1200	940	1300	1900
Inputs:					
AR u/s Whitecourt	1500	2300	650	420	770
McLeod River	140	240	130	66	100
MWPL effluent			320	610	600
Whitecourt STP effluent			2.5	1.6	6.0
3. AR at Athabasca	1900	2400	1600	2000	2200
Inputs:					
AR u/s L. Slave River	1900	1300	1100	1100	1300
Lesser Slave River	430	620	800	1400	1100
Athabasca STP effluent			0.0		12
4. AR d/s Ft. McMurray (near Bitumount)	1900	2600	2900		5100
Inputs:					
AR u/s Ft. McMurray	950	2000	2200		3300
Clearwater River	670	940	1700		1900
Ft. McMurray STP effluent			110		41
Suncor process effluent			16		16

3.16.3 Total Nitrogen

Total nitrogen is the sum of inorganic plus organic nitrogen. Organic nitrogen concentrations were greater than inorganic nitrogen concentrations; organic nitrogen was, on average, 65% of the total nitrogen concentrations along the entire Athabasca River. Therefore, trends of total nitrogen concentrations (Figure 23) in the river tended to reflect those of organic nitrogen (Figure 22).

Concentrations of total nitrogen varied from 0.2 mg/L below the Town of Athabasca (Survey 89-3) to 5.72 mg/L upstream of Grand Rapids (Survey 89-1). Total nitrogen concentrations increased downstream of Hinton due to the HCE loads (Table 24). Further increases occurred below Whitecourt, Athabasca and Ft. McMurray (Figure 23) and due primarily to loading from the MWPLE, the Lesser Slave River, and the Clearwater River, respectively (Table 24). The high values measured above the Pembina and Horse rivers were due to high TKN concentrations at those sites (Section 3.15.2). The high value (1.25 mg/L) measured 3 km downstream of Whitecourt in Survey 89-1 was likely a result of high nitrogen loading from the the McLeod River and the MWPLE.

The most extensive historical data sets for total nitrogen are for two sites in the lower Athabasca River (Figure 23). For these sites, concentrations measured during this study were within the historic range. At two sites during the 1988 and 1989 winter surveys, the ASWQO of 1.0 mg/L total nitrogen was exceeded. There is no CWQG for total nitrogen.

Figure 23. Winter Total Nitrogen Concentrations in the Athabasca River

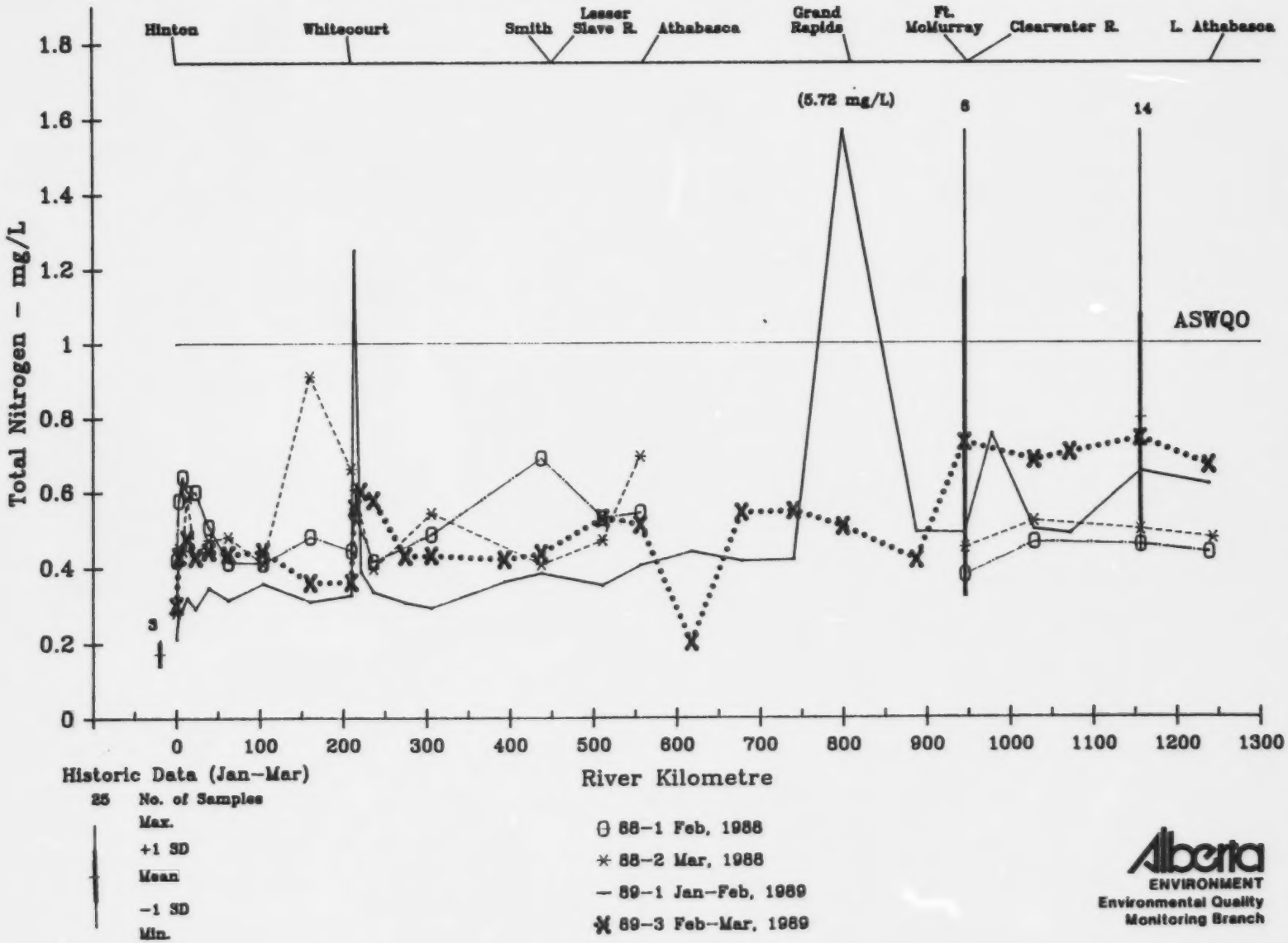

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TABLE 24. Mass load of total nitrogen at selected locations.

Locations	Load - kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	1400	1200	810		1100
Inputs:					
AR u/s HCE	910	760	570		730
HCE	600	550	240		340
2. AR d/s Whitecourt (25km)	1900	2000	1400	1800	2500
Inputs:					
AR u/s Whitecourt	1900	2900	1200	860	1400
McLeod River	210	430	230	180	230
MWPL effluent			320	620	600
Whitecourt STP effluent			32	31	33
3. AR at Athabasca	2600	4300	3100	2800	3300
Inputs:					
AR u/s L. Slave River	2600	2100	1900	1800	2000
Lesser Slave River	470	730	1100	1700	1300
Athabasca STP effluent					32
4. AR d/s Ft. McMurray (near Bitumount)	3600	5800	5500		8100
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	1700	3400	3200		4700
Clearwater River	1400	1900	2600		2800
Ft. McMurray STP effluent			490		160
Suncor process effluent			23		21

3.17 Phosphorus

Phosphorus (P) is the nutrient that limits productivity in most freshwater ecosystems (Wetzel, 1983). Increasing concentrations of P often result in increased biomass of algae, aquatic macrophytes, and associated biota. Phosphorus occurs in inorganic and organic compounds and in dissolved and particulate forms. Phosphorus is reactive; it sorbs readily to suspended and bottom sediments. Concentrations of phosphorus in rivers are highly variable and generally increases with discharge, as has been documented for the Athabasca River system (Blachford et al., 1985; Hamilton et al., 1985; Munn and Prepas, 1986).

Phosphorus loads from sewage and pulp mill effluents can be high. It is usually added to pulp mill effluents to enhance biological degradation of the pulping wastes. Benthic macroinvertebrate enrichment has been reported downstream of pulp mills, likely as a result of organic and inorganic load from the effluents (Bothwell and Stockner, 1980; Rabeni et al., 1985; Noton et al., 1989).

During the 1988 and 1989 surveys, total phosphorus (TP) concentrations in the Athabasca River upstream of Hinton ranged from 0.005 to 0.014 mg/L. Immediately downstream of Hinton, TP concentrations increased to about 0.03 mg/L, as a result of discharge from the HCE (Figure 24; Table 25). Concentrations then gradually declined downstream to about 0.01 mg/L upstream of Whitecourt (Figure 24). During survey 88-1, concentrations remained near that level to the Town of Athabasca. In contrast, in 1989, TP concentrations increased sharply downstream of Whitecourt to 0.05 to 0.16 mg/L. The increase in 1989 was a result of the high TP loads from MWPLE (Table 25). The increase in TP

Figure 24. Winter Total Phosphorus Concentrations in the Athabasca River

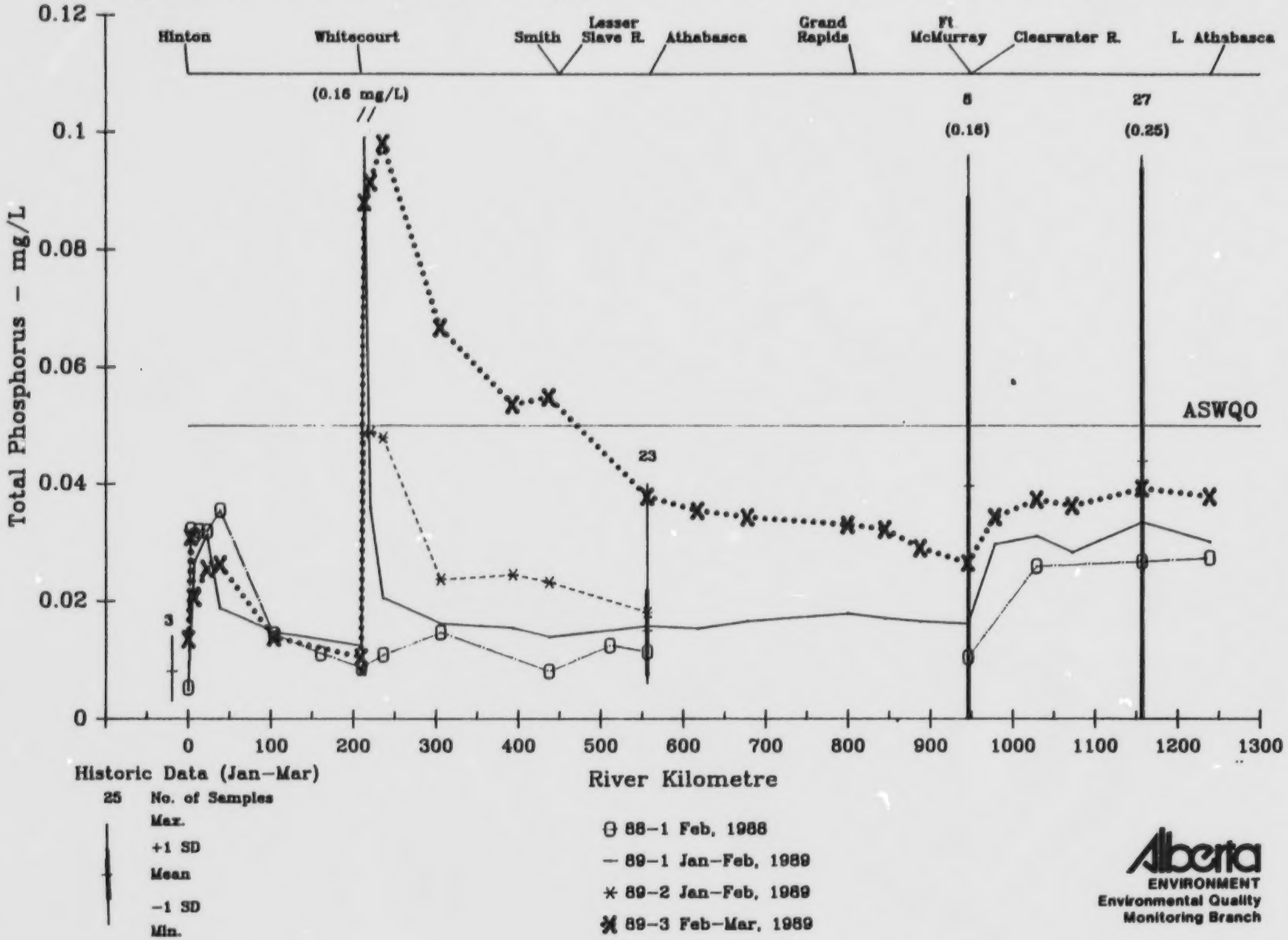

TABLE 25. Mass load of total phosphorus at selected locations.

Locations	Load - kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	72		87		64
Inputs:					
AR u/s HCE	11		13		33
HCE	61		190		54
2. AR d/s Whitecourt (25km)	49		84	200	430
Inputs:					
AR u/s Whitecourt	37		45	31	41
McLeod River	1.8		5.1	2.6	3.4
MWPL effluent			100	170	360
Whitecourt STP effluent			14	14	13
3. AR at Athabasca	54		120	110	250
Inputs:					
AR u/s L. Slave River	30		75	104	250
Lesser Slave River	22		46	49	41
Athabasca STP effluent			6.3		7.1
4. AR d/s Ft. McMurray (near Bitumount)	200	330	340		440
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	48	99	110		160
Clearwater River	110	170	210		200
Ft. McMurray STP effluent		50	47		14
Suncor process effluent		6.6	4.3		4.9

concentrations downstream of Whitecourt was greater, and persisted farther, for each successive survey in 1989. From the Town of Athabasca to upstream of Ft. McMurray, TP concentrations remained relatively constant. Downstream of Ft. McMurray, concentrations increased, primarily due to loading from the Clearwater River and secondarily from the Ft. McMurray STP.

Total phosphorus concentrations in the Athabasca River were not significantly ($P>0.05$) correlated to suspended solids ($r = 0.04$, $n=83$) or chlorophyll *a* concentrations ($r = 11$, $n=39$). Concentrations of total dissolved phosphorus (TDP) and TP in the Athabasca River were highly correlated ($r = 0.92$, $P<0.01$; Figure 25); on average, TDP was 53% of TP. Thus, TDP concentration followed a similar pattern to that described above for TP (Figure 26).

Concentrations of TP upstream of Hinton and in the lower Athabasca River were within the range reported for previous winters (Figure 24). No historic winter data were available for the reach immediately downstream of Whitecourt. However, it is probable that the values measured during 1989, the first winter that MWPL discharged effluent to the river, were high relative to previous years, because:

- TP load from the MWPLE was much higher than that from the McLeod River or Whitecourt STP (Table 25), which also discharge at Whitecourt,
- values measured prior to 1988 at Smith (n=2, both 0.01 mg/L), 227 km downstream from Whitecourt, were similar to concentrations measured in 1988, but lower than 1989, and
- in 1989, concentrations further downstream of Whitecourt, at the Town of Athabasca, were high relative to historic data (Figure 24).

Figure 25. Relationship of Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) in the Athabasca River, Winter 1988 and 1989.

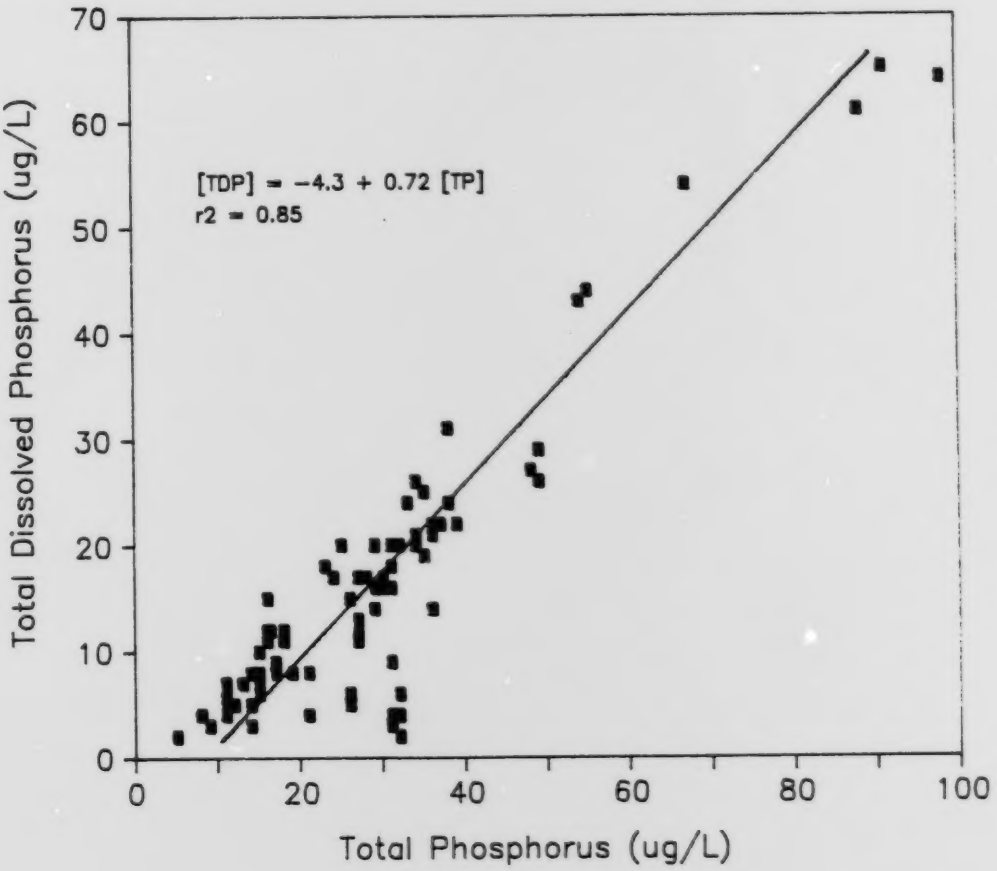

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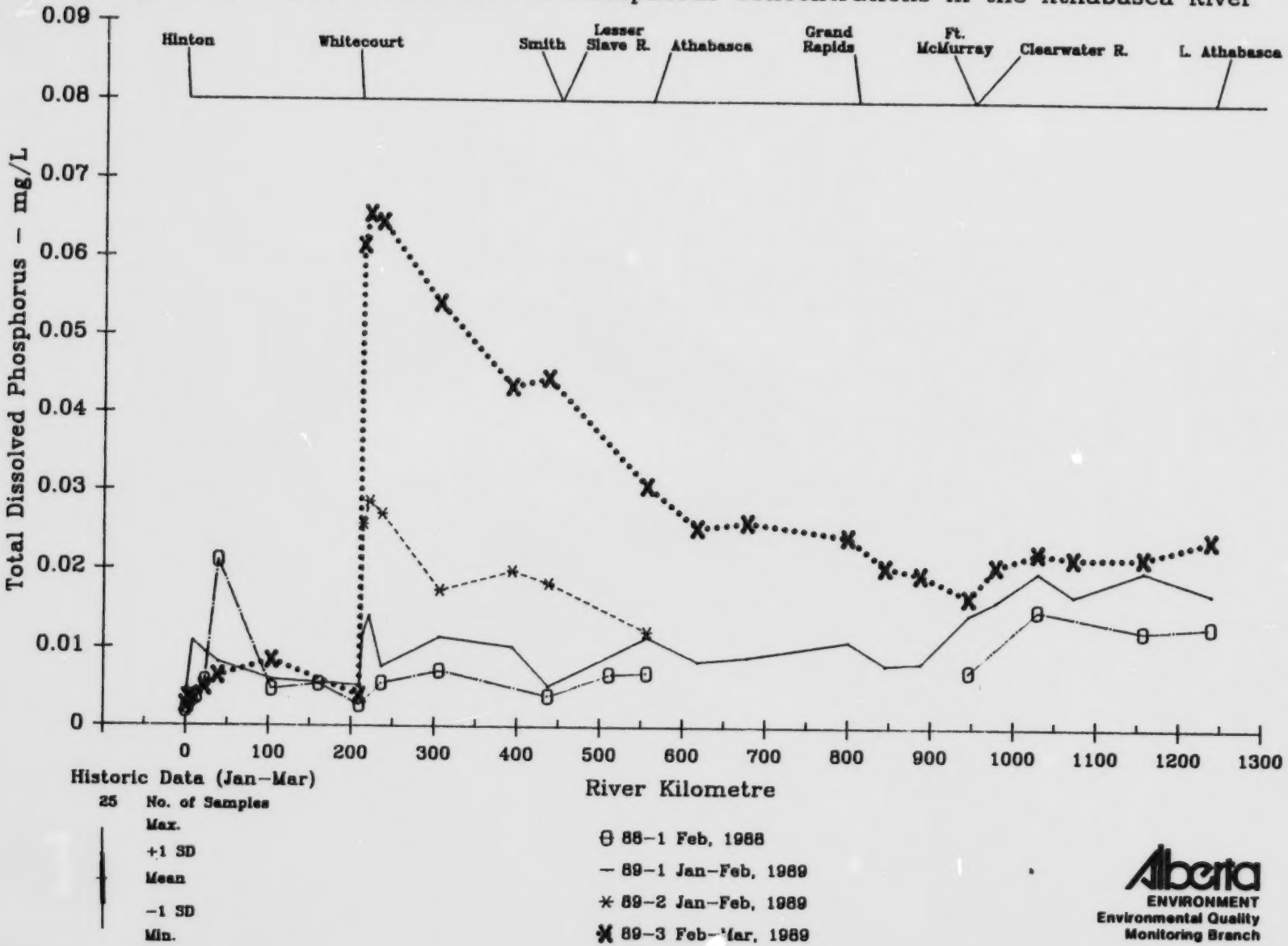
Figure 26. Winter Total Dissolved Phosphorus Concentrations in the Athabasca River



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In the Athabasca River, TP concentrations are highest in summer and lowest in winter (Hamilton et al., 1985). As a result of increased TP loading from the MWPLE, the reach of the Athabasca River between Whitecourt and the Town of Athabasca was non-compliant with the ASWQO of 0.05 mg/L for TP during surveys 89-1 and 89-3. All other reaches were compliant with the guideline. There are no CWQG for phosphorus. Possible consequences of maintaining high TP loads to the river from the MWPLE include nuisance growth of benthic algae and other organisms (Bothwell, 1989), increased sediment oxygen demand due to the former, and accelerated eutrophication of downstream water bodies.

3.18 Metals

Members of this group that were analyzed in 1989 were Al, As, Ba, Be, Cd, Ca, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, V, and Zn. All except Cu were also analyzed in 1988. All of these elements occur naturally in surface waters, and their concentrations are often positively correlated with the suspended solids content of the water. Thus, concentrations of these elements tend to increase as river discharge increases (Hem, 1970; Allan, 1986), and relatively low concentrations would be expected during winter.

In the Athabasca River, most of the metals were detected at low concentrations (Appendices 1 to 5). There were no general trends, with respect to concentrations along the river for Al, As, Be, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Se, V, or Zn. For most of these metals, concentrations in the pulp mill effluents were less than 10 times that of the upstream river water (Table 26). For Zn, concentrations in the pulp mill effluents were 100 times that in the river water. During this study,

TABLE 26. Ratio of metal concentrations in pulp mill effluents vs Athabasca River upstream of the effluents, maximum concentrations in the Athabasca River, and water quality objective or guideline.

METAL	RATIO		MAXIMUM VALUE	OBJECTIVE/ GUIDELINE
	HCE AR u/s Hinton	MWPLE AR u/s Whitecourt	mg/L	
Al	4.3	3.3	0.075	0.1[1]
As	1.8	6.3	0.0015	0.01[2]
Ba	1.9	2.1	0.122	1.0[2]
Be	b.d.	b.d.	b.d.	-
Cd	2.0	19	0.004	0.01[2]
Co	3.2	20	0.007	-
Cr	3.7	5.2	0.014	0.05[2]
Cu	11	43	0.007	0.02[2]
Fe	1	17	0.597	0.3[2]
Hg	8.0	b.d.	0.0004	0.0001[2]
Mn	282	96	0.055	0.05[2]
Mo	3.2	6.0	0.007	-
Ni	2.0	8.3	0.009	0.15[3]
Pb	5.9	1.0	0.009	0.05[2]
Se	b.d.	b.d.	b.d.	0.01[2]
V	1.7	5.2	0.0004	-
Zn	114	99	0.013	0.05[2]

1 CWQG for Freshwater Aquatic Life: pH $\geq$ 6.5, Ca^{2+} $\geq$ 4.0 mg/L, DOC $\geq$ 2.0 mg/L.
2 ASWQO
3 CWQG for Freshwater Aquatic Life: hardness > 180 mg/L ($CaCO_3$).
- (dash) no ASWQO or CWQG for that parameter.
bd concentration below detection limit; ratios were not calculated

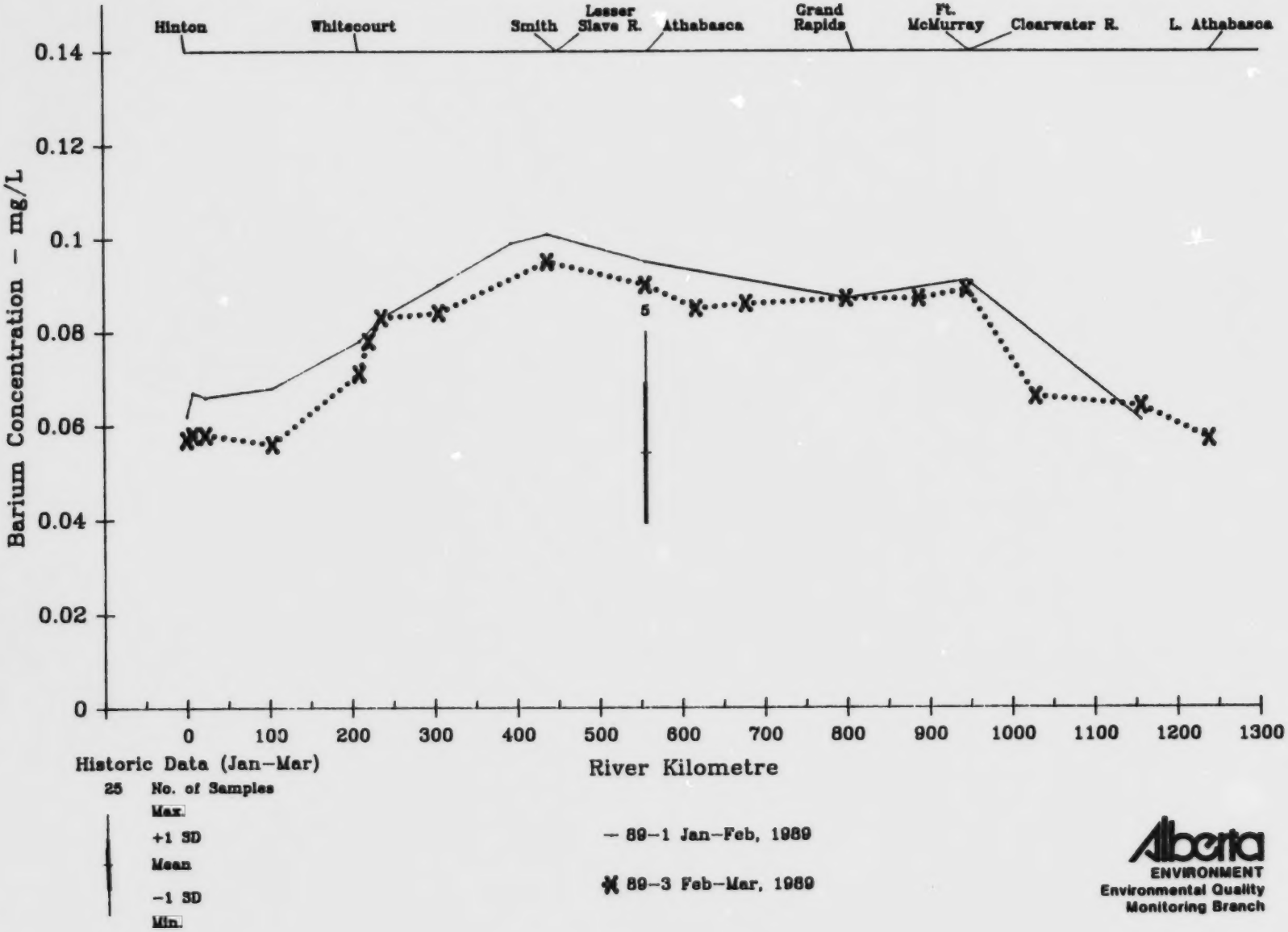
there were no observed impacts from the pulp mill effluents, other effluents, or tributaries on downstream concentrations of these metals (Appendix 1 to 5). In contrast, there were distinct trends in concentrations of Ba, Fe, and Mn along the Athabasca River; these metals are discussed in more detail below.

Barium is a common element in the earth's crust, but only low levels of Ba (<1 mg/L) are found in most surface waters (CCREM, 1987). Near Hinton, Ba concentrations were about 0.06 mg/L and increased to about 0.1 mg/L upstream of Smith (Figure 27). The increase was primarily due to loading from numerous small tributaries within that reach. Concentrations of Ba in those tributaries were relatively high (0.061 to 0.17 mg/L), probably because of geochemical weathering of Ba from rocks (CCREM, 1987).

Concentrations of Ba in effluents were similar to those in most tributaries. Downstream of Smith and Ft. McMurray, Ba concentrations decreased, partly due to dilution from the Lesser Slave River (mean 0.065 mg/L) and Clearwater River (mean 0.02 mg/L), respectively. In addition, Ba is readily removed from the water column by sorption and sedimentation (CCREM, 1987). The only historic winter data for Ba were collected at the Town of Athabasca, from 1984 to 1987 (Figure 27). Barium concentrations at that site during the winter 1988 and 1989 surveys appeared to be higher than historic values, but only five historic values are available.

Iron is the fourth most abundant element in the earth's crust; it enters surface waters through weathering of rocks and anthropogenic activity (CCREM, 1987). Upstream of Hinton, Fe concentrations were

Figure 27. Winter Barium Concentrations in the Athabasca River



highly variable between surveys, ranging from <0.1 mg/L to about 0.4 mg/L. However, 100 km downstream of Hinton, Fe concentrations during all surveys were about 0.06 mg/L (Figure 28). Concentrations gradually increased to about 0.15 mg/L upstream of Ft. McMurray. High Fe loads from the Clearwater River (Table 27) and other tributaries caused a dramatic increase in Fe concentrations downstream of Ft. McMurray. Iron loads from the effluents were low relative to natural loads from tributaries (Table 27). Iron concentrations in the Athabasca River during the winters of 1988 and 1989 were within the range of historic values (Figure 28).

Manganese enters aquatic environments from weathering of metamorphic and sedimentary rocks and from soils and sediments (CCREM, 1987). It is an essential trace element for micro-organisms, plants, and animals. Manganese concentrations upstream of Hinton were low (0.01 mg/L) and increased to 0.03 - 0.045 mg/L downstream of Hinton due to loading from the HCE (Figure 29, Table 28). During 1989, slight increases (~0.005 mg/L) in Mn concentrations occurred downstream of Whitecourt, due primarily to loading from the MWPLE (Table 28). From Whitecourt to Ft. McMurray, Mn concentrations were relatively constant, ranging from 0.005-0.015 mg/L. Concentrations increased sharply downstream of Ft. McMurray, to about 0.04 mg/L, due to loading from the Clearwater River (Table 28). Manganese concentrations in the Athabasca River during the winters of 1988 and 1989 were within the range of historic values (Figure 29).

Figure 28. Winter Total Iron Concentrations in the Athabasca River

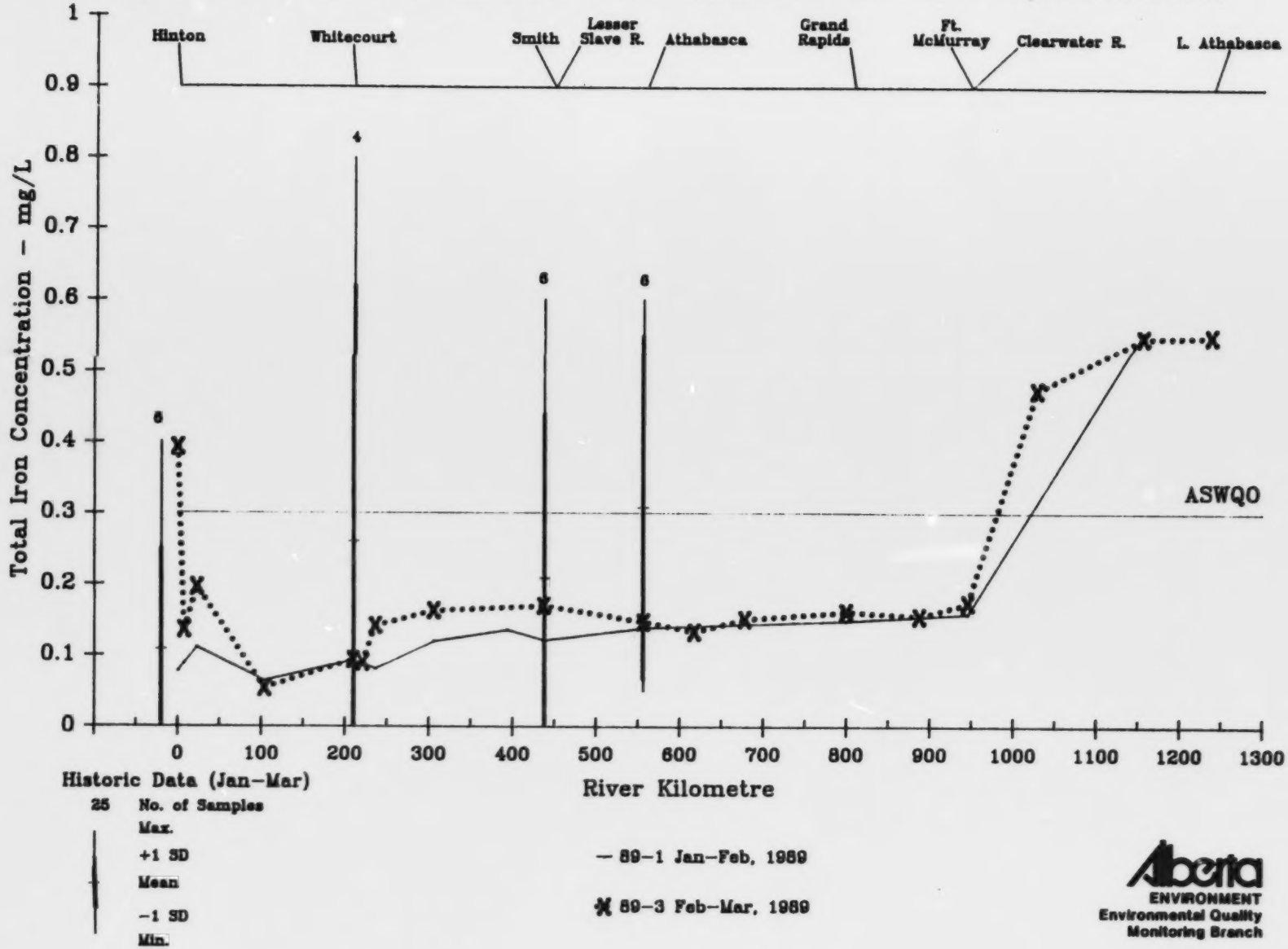


TABLE 27. Mass load of iron at selected locations.

Locations	Load - kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	340		310		490
Inputs:					
AR u/s HCE	220		210		950
HCE			43		24
2. AR d/s Whitecourt (25km)			330	480	620
Inputs:					
AR u/s Whitecourt	380		340	360	370
McLeod River	19		30	29	42
MWPL effluent			16	15	14
Whitecourt STP effluent			0.2	0.2	0.2
3. AR at Athabasca	570		1000	1000	960
Inputs:					
AR u/s L. Slave River	480		650	770	790
Lesser Slave River	220		570	590	360
Athabasca STP effluent					0.4
4. AR d/s Ft. McMurray (near Bitumount)		4300			5600
Inputs:					
AR u/s Ft. McMurray (near Horse R.)		1100			1100
Clearwater River		2400			3500
Ft. McMurray STP effluent					0.7
Suncor process effluent					15

Figure 29. Winter Total Manganese Concentrations in the Athabasca River

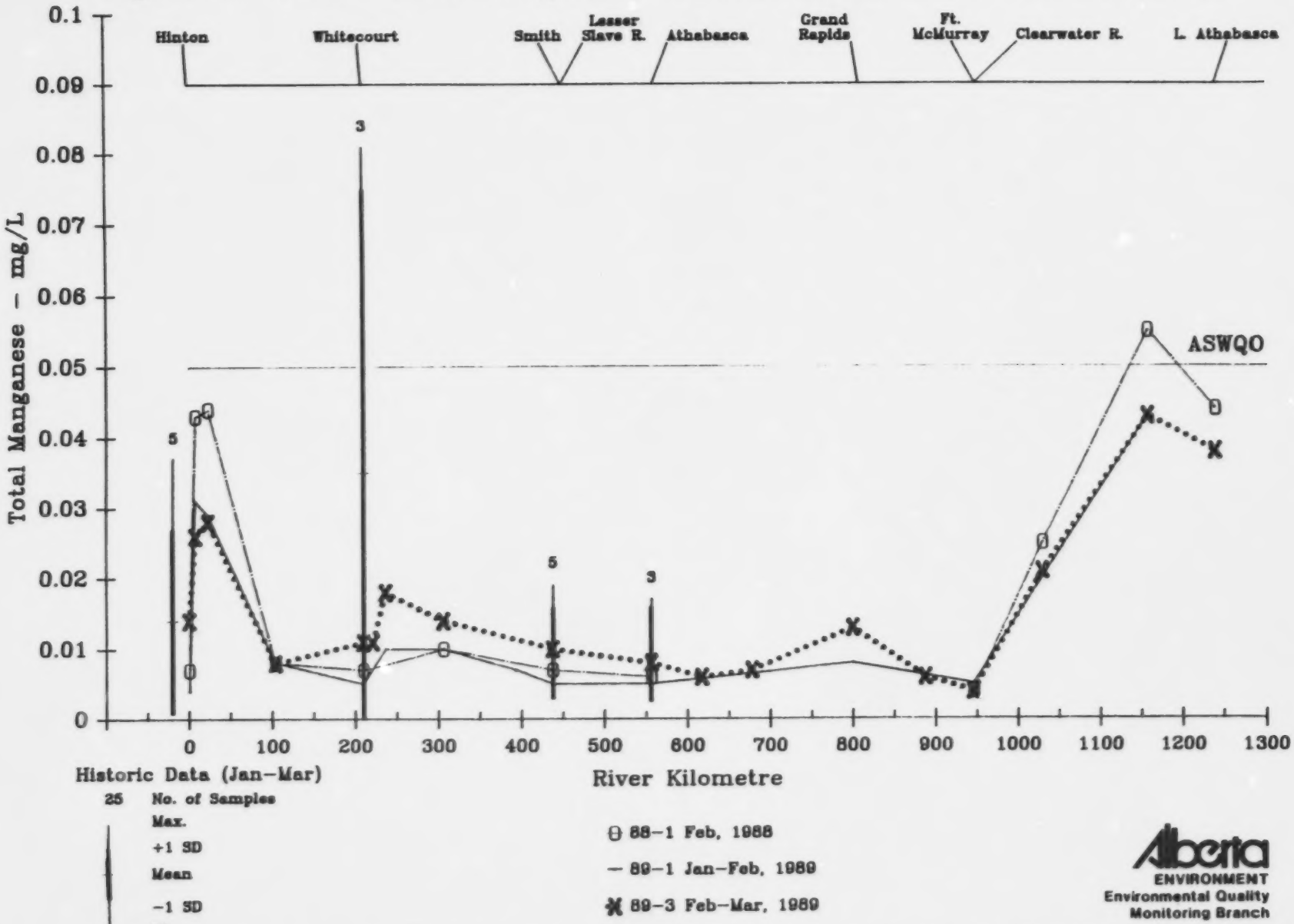


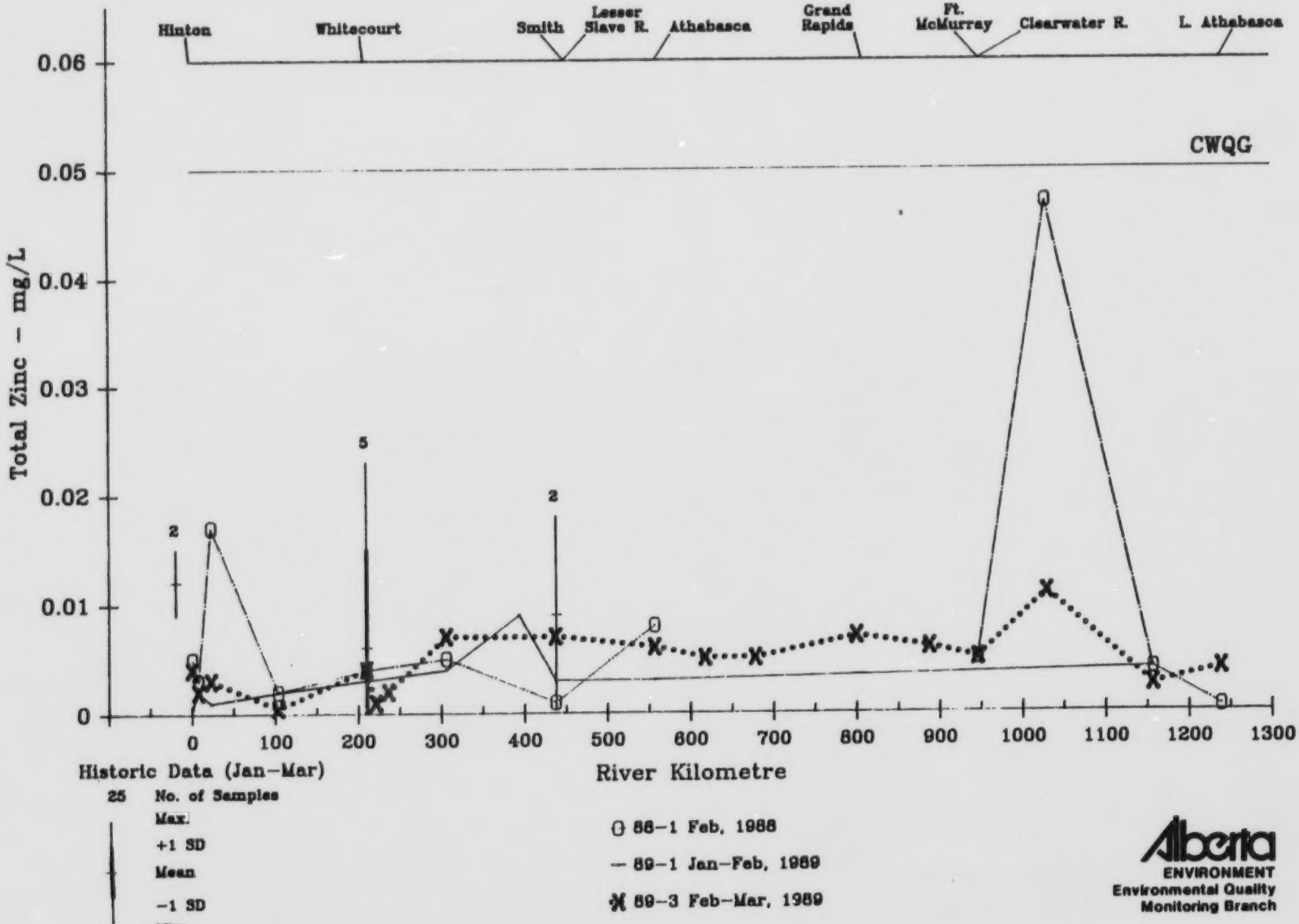
TABLE 28. Mass load of manganese at selected locations.

Locations	Load - kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	99		81		70
Inputs:					
AR u/s HCE	15		12		34
HCE	80		66		55
2. AR d/s Whitecourt (25km)			41	58	78
Inputs:					
AR u/s Whitecourt	29		18	26	43
McLeod River	2.2		2.9	2.9	4.0
MWPL effluent			11	15	12
Whitecourt STP effluent			0.4	0.2	0.3
3. AR at Athabasca	29		38	48	52
Inputs:					
AR u/s L. Slave River	26		27	40	46
Lesser Slave River	65		76	91	76
Athabasca STP effluent					0.1
4. AR d/s Ft. McMurray (near Bitumount)	190	160			250
Inputs:					
AR u/s Ft. McMurray	18	30	33		25
Clearwater River	100	100	220		210
Ft. McMurray STP effluent		0.7			0.2
Suncor process effluent		1.2			1.6

Zinc enters aquatic environments primarily from weathering of rocks and anthropogenic inputs (CCREM, 1987). It is essential element for aquatic biota and is readily bioaccumulated (USEPA, 1980). Concentrations of zinc in the pulp mill effluents were about 100 times that of the upstream river water (Table 26). However, no consistent trends in Zn concentrations were observed (Figure 30). Patterns in the river may have been obscured because of anomalously high values due to sample contamination; relatively high Zn concentrations were detected in blank samples (Appendix 11). There are few records of Zn concentrations from previous winters. Even so, Zn concentrations in the Athabasca River during the winters of 1988 and 1989 were generally similar to values recorded in previous years.

During the winter 1988 and 1989 surveys, the maximum concentration of all metals analyzed in this study, except for Fe, Hg, and Mn, were below the ASWQO or CWQG (Table 26). Iron exceeded the ASWQO of 0.3 mg/L upstream of Hinton (Survey 89-3) and downstream of Ft. McMurray. The high values upstream of Hinton may have been a result of sample contamination, because Fe was detected in some blank samples (Section 3.1.2.2). The exceedences downstream of Ft. McMurray were due to natural Fe loads to the river, in which case the ASWQO do not apply (Section 2.5). The ASWQO of 0.0001 mg/L for Hg was exceeded on one occasion, during Survey 89-1 at a site downstream of Hinton. The ASWQO of 0.5 mg/L for Mn was exceeded on one occasion, during Survey 88-1 in the lower Athabasca River (Figure 29).

Figure 30. Winter Total Zinc Concentrations in the Athabasca River



3.19 Bacteria

Bacteria occur naturally in surface waters and consume detritus and other organic material. Numerous species of bacteria occur in surface waters; their density is often correlated to the amount of organic material present. These bacteria are generally not pathogenic to humans. Wastewater, which contains sewage or elevated amounts of organic material, usually contains relatively high densities of bacteria. If human or warm-blooded animal sewage is present in wastewater, pathogenic bacteria could be present. Bacterial analysis is often used to test for the presence of sewage or fecal contamination. In this study, bacterial analyses included total coliform and fecal coliform bacteria tests, and a standard plate count for heterotrophic bacteria.

3.19.1 Total Coliforms

Total coliform bacteria include several rod-shaped species that ferment lactose at 35°C with gas formation in standard laboratory tests (Greenberg et al., 1985). These bacteria are heterotrophic and include those naturally occurring and of those fecal origin. As a result, the total coliform test is not a good pollution indicator; the density of total coliforms may be related to the presence of natural organic material or the presence of sewage or organic-rich wastewaters. The main use of the total coliform test is to check treated drinking water (Health and Welfare Canada, 1983).

In all surveys, total coliform densities in the Athabasca River were below 150/100 mL. Increases in total coliform densities occurred below Hinton (Figure 31). The increase was likely due to loading from the HCE (Table 29), although HCE did not always balance the downstream

Figure 31. Winter Total Coliforms Concentrations in the Athabasca River

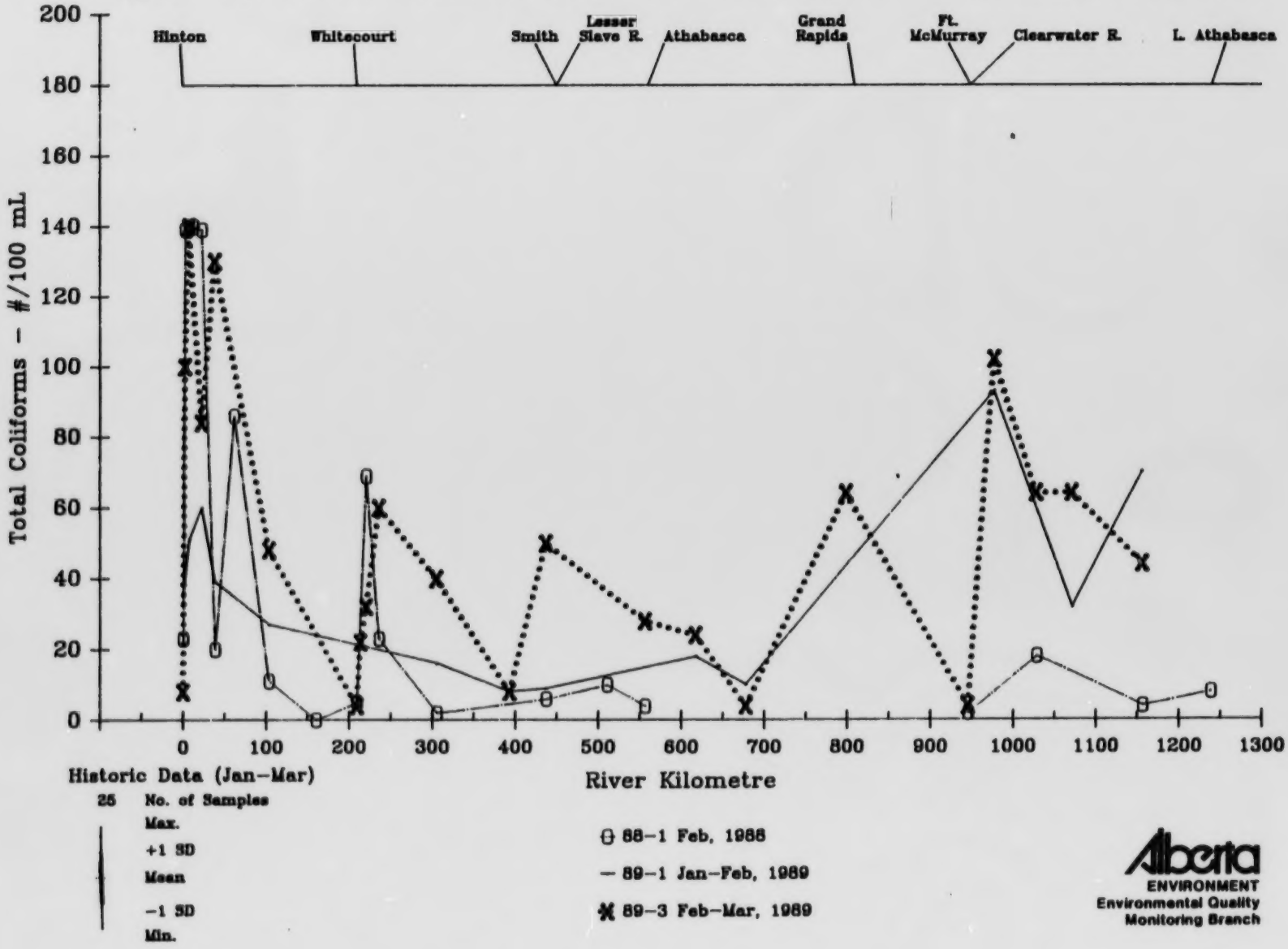


TABLE 29. Mass load of total coliforms at selected locations.

Locations	Load - 1000 pseudo kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	310		170		210
Inputs:					
AR u/s HCE	49		94		19
HCE			59		12
2. AR d/s Whitecourt (25km)	110			220	260
Inputs:					
AR u/s Whitecourt	20			22	16
McLeod River	1.1			0.2	4.8
MWPL effluent			12	8.3	
Whitecourt STP effluent			6.2	1.0	6.0
3. AR at Athabasca	19			3.0	180
Inputs:					
AR u/s L. Slave River	22		48	27	230
Lesser Slave River	45		4.1	4.1	31
Athabasca STP effluent					11
4. AR d/s Ft. McMurray (near Bitumount)	140	1200			760
Inputs:					
AR u/s Ft. McMurray (near Horse R.)	9.2	300			25
Clearwater River	6.2	280			72
Ft. McMurray STP effluent		1000			84
Suncor process effluent					

Pseudo - kg/d calculated by expressing counts/100mL as mg/L.

river loads. Problems with the mass balance may be a result of factors discussed in Section 2.4. There were also increases in total coliform concentrations downstream of Whitecourt in both years (Figure 31; Appendix 4). and concentrations increased downstream of Ft. McMurray, due primarily to the Ft. McMurray STP and secondarily to the Clearwater River (Table 29).

During this study, total coliform densities were not significantly ($P > 0.05$) correlated to DOC concentrations in the Athabasca River, its tributaries or effluents. However, high densities of total coliforms generally coincided with high DOC concentrations in the HCE.

Concentration of total coliforms during the 1988 and 1989 surveys were generally within the range of historic data (Table 30). Near the mouth of the river at Old Fort, concentrations were less than historical densities, but few historic data are available for that site.

For potable supply to treatment facilities and non-contact recreation, the ASWQO for coliform bacteria states that for $\geq$ 5 samples within a 30 day period, 90% of samples should have < 5000/100mL total coliforms. No total coliform densities measured in the winter surveys exceeded 5000/100mL (the maximum was 182/100mL).

3.19.2 Fecal Coliforms

Fecal coliform bacteria are those total coliforms that respond an incubation temperature of 44.5°C. The test is used as an indicator for fecal contamination from warm-blooded animals. However, the fecal coliform test is not specific. In addition to Escherichia coli (the indicator of fecal contamination), Klebsiella species react positively in

TABLE 30. Summary of historic winter data for bacteria at selected sites in the Athabasca River.

PARAMETER	U/S HINTON	U/S WHITECOURT	U/S SMITH	AT THE TOWN ATHABASCA	U/S FT. MCMURRAY	AT OLD FORT
Total Coliforms						
Median	23	12	44	24	55	295
Range	0-920	0-1800	0-1800	0.5-3600	33-336	130-600
n	16	12	15	45	8	4
Fecal Coliforms						
Median	3.3	1	4.5	6.3	16	56
Range	0-54	0-10	0-130	0.5-90	0.33	12-130
n	16	12	15	45	8	4
Standard Plate Count						
Median	250	3650	1500	3500	1300	500
Range	30-21,000	700-32,000	20-450,000	600-45,000	500-2400	1200-30,000

Total and Fecal Coliforms in counts/100mL.
Standard Plate Count in counts/mL.

this test. Klebsiella species are common bacteria in vegetable matter, e.g., bark, and are known to occur and grow in organically rich water such as pulp and paper mill effluents (Poole et al., 1978; Health and Welfare Canada, 1983).

In all surveys, fecal coliform densities were less than 12/100 mL in the Athabasca River. In Survey 89-1, fecal coliform densities increased downstream of Hinton due to loading from the HCE (Figure 32, Table 31). In the other surveys, fecal coliform loads from the HCE were much lower and there were no increases in densities downstream of the effluent. Densities of fecal coliforms also varied substantially in the MWPLE (range from less than 1/100 mL to 700/100 mL), although densities in the river downstream of Whitecourt were not greatly affected. An increase in fecal coliform densities occurred downstream of Ft. McMurray (Figure 32) due to loading from the Clearwater River and Ft. McMurray STP (Table 31).

Fecal coliform densities in the Athabasca River, determined during the 1988 and 1989 winter surveys, were within the historic data range (Table 30). Concentrations of fecal coliforms at Old Fort were relatively low compared to the historic median value, although there are few historic data for that site.

For potable supply to treatment facilities and non-contact recreation, the ASWQO for fecal coliforms is the same as for total coliforms, except that 90% of the samples should have less than 1000/100mL. No fecal coliform densities measured in the Athabasca River during this study were greater than 12/100mL.

Figure 32. Winter Fecal Coliform Concentrations in the Athabasca River

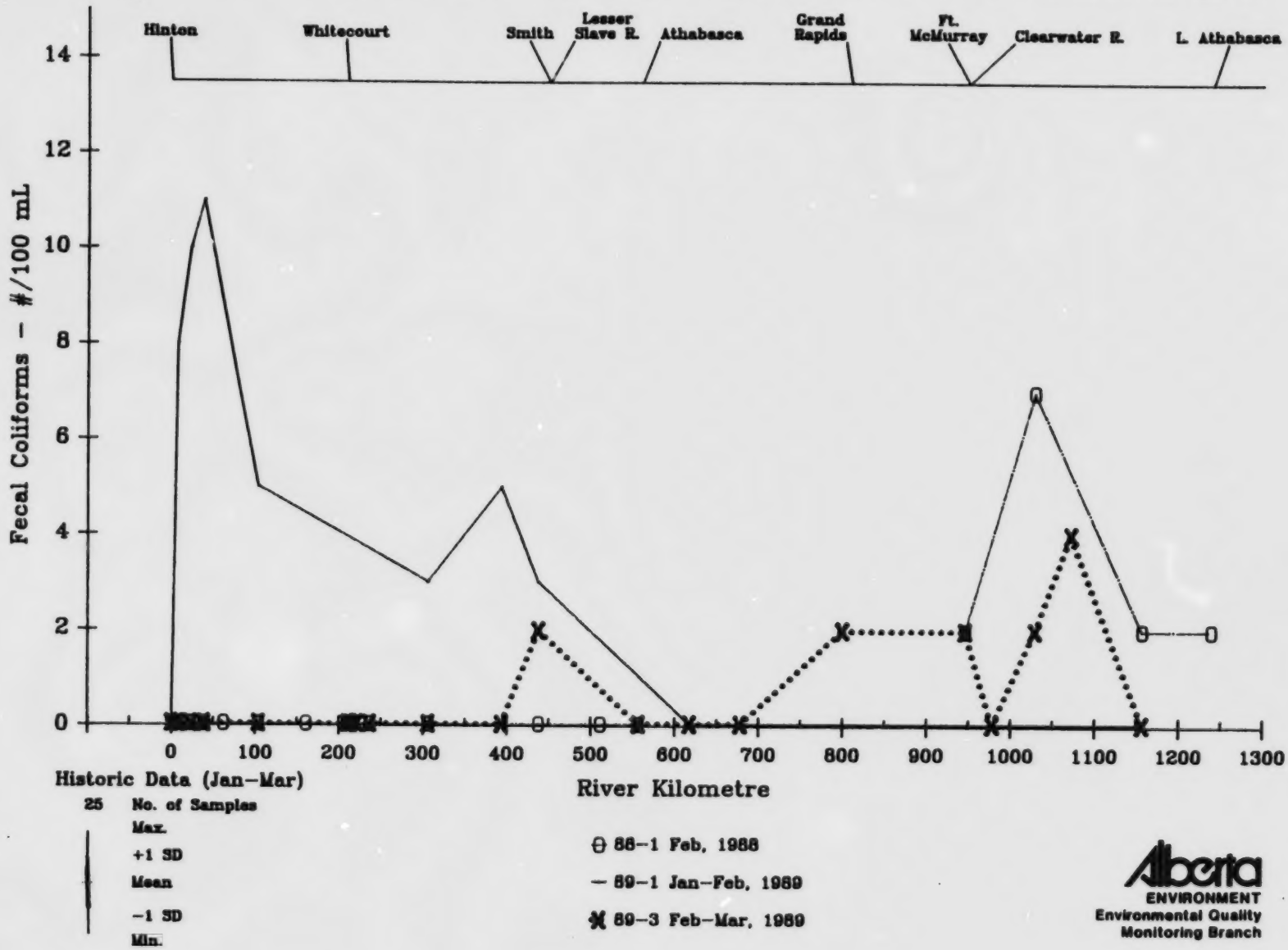


TABLE 31. Mass load of fecal coliforms at selected locations.

Locations	Load - 1000 pseudo kg/d				
Survey:	88-1	88-2	89-1	89-2	89-3
1. AR d/s Hinton (20km)	1.1		28		1.3
Inputs:					
AR u/s HCE	1.1		1.4		1.2
HCE	0.8		25		0.0
2. AR d/s Whitecourt (10km)	2.3			21	2.2
Inputs:					
AR u/s Whitecourt	2.1			1.9	2.0
McLeod River	0.2			0.2	0.2
MWPL effluent			8.5	0.0	
Whitecourt STP effluent			1.8	0.9	0.0
3. AR at Athabasca	2.4			3.0	3.3
Inputs:					
AR u/s L. Slave River	1.9		16	2.2	9.3
Lesser Slave River	0.5		1.1	1.3	1.0
Athabasca STP effluent					0.7
4. AR d/s Ft. McMurray (near Bitumount)	54	23			24
Inputs:					
AR u/s Ft. McMurray	9.2	15			12
Clearwater River	6.2	7.3			2.0
Ft. McMurray STP effluent					2.3
Suncor process effluent					

Pseudo - kg/d calculated by expressing counts/100mL as mg/L.

3.19.3 Standard Plate Count

This test is a comparatively non-selective test for heterotrophic bacteria, i.e., bacteria that decompose organic material (Greenberg et al., 1985). This test detects many naturally occurring species as well as species present in wastewaters and is not an indicator of pathogens. The density of bacteria detected in this test should be broadly correlated to the amount of organic matter present.

Standard Plate Counts (SPC) were generally below 40,000/mL. Higher counts were observed 20 km downstream of Hinton; 181,000/mL (Survey 89-1). No general pattern of increases in SPC was apparent downstream of pulp mill or sewage plant effluents, even though counts in the effluents were generally high (range 100/mL in Slave Lake STP to 850,000/mL in the HCE). Bacteria are characteristic of wastewater treatment processes and are the main agents of organic decomposition in pulp mill effluent lagoons.

High values of SPC coincided with high concentrations of organic matter (DOC) in effluents of pulp mills and sewage treatment plants. However, SPC and DOC were not significantly correlated ($P > 0.05$) in samples from the Athabasca River or from tributaries and effluents. Standard plate counts in the Athabasca River in 1988 and 1989 winter surveys were within the range reported for previous winters. There are no ASWQO or CWQG for heterotrophic bacteria.

3.20 Other Parameters

In addition to the parameters discussed above, a number of others were analyzed as part of this study: temperature, pH, alkalinity, hardness, fluoride, BOD (dissolved)-5d, BOD-10d, BOD-14d, and chemical

oxygen demand (COD) (Appendices 1 to 5). There were no effects on the values of pH, hardness, and fluoride in the Athabasca River as a result of effluent discharge. Temperature increased slightly (<1°C) downstream of Hinton and Whitecourt due to the HCE and MWPLE, respectively. The temperature increase results in winter ice-free reaches downstream of the two pulp mill effluents (Section 3.1.3). Alkalinity increased about 20 mg/L downstream of Whitecourt due in part to the MWPLE. The effect on alkalinity would have little or no environmental impact. The oxygen demand parameters (BOD and COD) were collected for use in modelling winter oxygen conditions in the Athabasca River and are described in another report (HydroQual Consultants Inc., in prep.).

4. GENERAL DISCUSSION

As noted earlier, this report presents and interprets the results of winter water quality surveys carried out in 1988 and 1989. Since river discharge is lowest in winter, the results represent a time of low dilution capacity in the river and therefore a time when any effluent impacts would be greatest. Any impacts to river water quality would likely be much less pronounced during other times of the year; however, winter flow conditions persist for about three to four months of the year.

This work represent the findings from only two winters: conditions in other winters may differ as a result of natural annual variation in river and tributary water quality, discharge rates, and effluent loads. Historic fluctuations in river quality have been illustrated on the figures for the various water quality variables. Variation in discharge occurs from winter to winter. Discharge during the two winters was generally below average, but greater than the $7Q_{10}$ flows (Table 2). Had higher flows occurred during 1988 and 1989, the impacts noted for several parameters probably would have been less pronounced; whereas, had lower flows occurred, the impacts would have been more severe.

Effluent loads for various constituents also fluctuate over time (Table 32) and obviously will influence the degree of impact on water quality. For most parameters, the effluents sampled during these surveys were in compliance with their licence conditions (Table 32). In many instances, the effluents were considerably lower than their licence limits, i.e., the HCE for BOD and SS; the MWPL effluent for colour; the

TABLE 32. Effluent water quality and licence limits, winter 1988 and 1989.

EFFLUENT AND PARAMETER	UNITS	LICENCE LIMIT	OBSERVED, BY SURVEY				
			88-1	88-2	89-1	89-2	89-3
HINTON COMBINED							
BOD_5	kg/d	6,600	4,400	2,700	2,500	-	1,800
Suspended solids	kg/d	13,900	4,900	-	3,500	-	3,300
pH	pH units	6.5-9.5	7.5	7.0	5.2	-	7.7
Colour (true)	'pseudo' kg/d	197.75	200	84.1	106.4	-	188.6
MILLAR WESTERN PULP LTD.							
BOD_5-monthly mean	kg/d	5,100					
-daily max	kg/d	10,200	0	0	7,700	6,000	6,000
Suspended solids-monthly mean	kg/d	20,400					
-daily max	kg/d	27,200	0	0	22,900	19,600	23,600
pH	pH units	6.5-9.5	0	0	8.0	8.1	8.1
Colour (true)	'pseudo' kg/d	30,600	0	0	4,900	3,800	8,000
WHITECOURT STP							
BOD_5	mg/L	25	-	-	6.4	5.3	8.1
Suspended solids	mg/L	25	-	-	4	4	14
SLAVE LAKE STP							
BOD_5	mg/L	25	-	-	6.4	7.3	18.7
Suspended solids	mg/L	25	-	-	16	20	20
ATHABASCA STP							
BOD_5	mg/L	25	-	-	9	-	8
Suspended Solids	mg/L	25	-	-	9	-	8
FT. MCMURRAY STP							
BOD_5	mg/L	25	-	-	18.9	-	70
Suspended Solids	mg/L	25	-	-	15	-	6
SUNCOR INC. PROCESS EFFLUENT		(monthly mean)					
COD	kg/d	4,220	-	1,100	820	-	770
Phenolics	kg/d	8.4	-	0.26	0.20	-	0.21
Ammonia-N	kg/d	136	-	6.1	3.0	-	1.5
Oil and Grease	kg/d	210	-	96	82.6	-	72.5
Suspended Solids	kg/d	1,000	-	200	350	-	290

STP effluents for BOD and SS; and the Suncor effluent for COD, phenolics, ammonia, oil and grease, and suspended solids. Impacts on water quality would be more severe, if one or both of the pulp mills were to discharge their licenced loads for these parameters, particularly if they coincided with low flows in the Athabasca River. In contrast, the Suncor process and the sewage treatment plant effluents generally are not of sufficient magnitude to markedly affect river water quality for parameters considered in the licenses.

These winter surveys on the Athabasca River system indicate that effluents from the pulp mills adversely affected concentrations of dissolved oxygen, phenolic compounds, trace organic compounds, colour, odour, phosphorus, and manganese, to the extent that some became non-compliant with the ASWQO or the CWQG (Table 33). The pulp mill effluents also increased river concentrations of sodium, chloride, sulphate, suspended solids, tannin and lignin, organic carbon, nitrogen, and bacteria. These effects are consistent with the findings of water quality impact assessments carried out previously with regard to the HCE (A.M. Anderson, pers. comm., EQMB, Alberta Environment; Clayton 1972; Hamilton et al., 1985) and the bleached kraft mill effluent on the Wapiti-Smoky River system near Grande Prairie (Noton et al., 1989). This is the first study that documents the effects due to the MWPLE. In contrast to the pulp mills, the municipal STP effluents had much less impact on river quality, although there were effects on nitrogen, phosphorus, and bacteria concentrations. No effect of the Suncor process on river water quality was discernible.

TABLE 33. Synopsis of winter water quality conditions in the Athabasca River, 1988 and 1989.

SELECTED PARAMETERS	DESCRIPTION AND KEY FEATURES	COMPLIANCE WITH: ASWQO	CWQG
Oxygen	Declined from Hinton to Smith, largely due to pulp mill effluents (record low at Smith); increased due to Lesser Slave River inflow and Grand Rapids re-aeration.	YES	NO
Major Ions	Sodium and chloride increased by HCE and Clearwater River. Sulphate increased by HCE and diluted by tributaries.	NS	YES
Suspended solids	Low in winter; local increases due to pulp mills.	YES	YES
Organic Carbon	Increase due to HCE, slight increase due to MWPLE; general increase d/s due to tributary inflow.	NS	NS
Phenolics	Major increase due to both pulp mills; downstream tributaries naturally high.	NO	NO
Tannin and Lignin	Major increase due to HCE; d/s tributaries contain moderate concentrations.	NS	NS
Trace Organic Compounds	Increase due to HCE; some persist d/s.	NS	YES*
Colour	Major increase due to HCE; d/s tributaries naturally coloured.	NO	NS
Odour	Noticeable increase due to HCE; persistent downstream.	-	NO
Nitrogen	Some increases in N fractions primarily due to pulp mills and secondarily STP effluents.	YES	YES
Phosphorus	Major increase due to pulp mills, minor increase due to Ft. McMurray STP.	NO	NS
Iron	Major increases due to Clearwater River.	NO	NO
Manganese	Major increase due to pulp mills and d/s tributaries.	YES	YES
Zinc	High load from pulp mills but river quality no affected.	YES	YES
Other metals	Al, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Se, and V not affected by effluents.	YES	-
Bacteria	Fecal and total coliforms increased somewhat due to pulp mills and some STP effluents.	YES	YES

NS not specified.
* for compounds addressed by CWQG.

The consequences, or effects on use, of the impacts on various parameters have been discussed previously under each parameter heading. Despite the impacts, benthic macroinvertebrates (insects, 'worms', snails, etc. that inhabit the river bed) in the Athabasca River continue to be present in more or less 'reasonable' numbers and diversity of types (A.M. Anderson, pers. comm., EQMB, Alberta Environment, unpublished data). Other impacts on aquatic biota that have been reported to result from pulp mill effluents, such as contamination by chlorinated organic compounds and tainting of fish (Alberta Environmental Centre, 1987; McLeay and Associates, 1987), have not been investigated in the Athabasca River system.

5. TECHNICAL SUMMARY

In view of the rapid expansion in the pulp mill industry in the Athabasca River Basin and because the lowest flow and dilution capacity occurs during the winter, five water quality surveys were carried out in January to March, 1988 and 1989. These surveys were designed to obtain further baseline data, to better describe any existing impacts, and to obtain data for water quality protection planning. Two of the surveys covered the length of the river. A wide range of parameters were sampled and extensive quality control procedures were included. Continuous monitoring of oxygen was also done. This report presents and interprets data collected during the surveys, compares the findings to past water quality conditions, assesses the impact of the various effluents to the river, and compares river water quality to the ASWQO and the CWQG (Table 33).

During both years, river flows were about 70% of the long term average winter flows. Effluents discharging to the river were the Hinton combined pulp mill / municipal effluent (HCE), the Millar Western Pulp Ltd. (MWPL) effluent (1989 only), Whitecourt sewage, Town of Athabasca sewage, Ft. McMurray sewage, and the Suncor Oil Sands process effluent.

Dissolved oxygen (DO) in the Athabasca River was about 11.5 mg/L upstream of Hinton. In both years, DO concentrations declined downstream of Hinton, at least in part due to the HCE. In 1989, DO also declined noticeably downstream of Whitecourt, due to the MWPL effluent. Dissolved oxygen was about 6 mg/L upstream of Smith in 1989, the lowest value on record. The Lesser Slave River inflow and re-aeration in Grand Rapids raised river oxygen to about 12 mg/L near Ft. McMurray. Dissolved oxygen

concentrations complied with the ASWQO of 5 mg/L, but not with the CWQG.

Total dissolved solids were about 250 mg/L throughout the river and were not greatly affected by effluents. Sodium and Cl^- increased markedly due to the inflow of the HCE and the Clearwater River. In 1989, Na^+ concentrations increased due to the MWPL effluent. Both Na^+ and Cl^- increased in concentration from Hinton to Lake Athabasca whereas $SO_4^=$ decreased, due to dilution by tributaries. The HCE increased sulphate about 10% downstream of Hinton. Sodium, Cl^-, and $SO_4^=$ concentrations all complied with water quality guidelines.

Sulphide concentrations were less than 0.004 mg/L throughout most of the river, but local increases were observed downstream of the HCE. The maximum sulphide concentration measured in the river (0.008 mg/L) was much lower than the ASWQO.

Silica increased in concentration down the river, primarily because of the inflow of tributaries with higher silica concentrations. No guidelines exist for silica.

Suspended solids were generally less than 10 mg/L throughout the river. Local increases occurred downstream of both pulp mills. Other effluents did not affect river SS concentrations.

Concentrations of 'oil and grease' in the Athabasca River did not exceed 0.6 mg/L and were usually much lower. These were likely natural compounds. The effluents contained higher concentrations, but had no discernible effect on river concentrations, which complied with the ASWQO.

Phenolics concentrations were less than 0.001 mg/L upstream of Hinton and were raised markedly by the HCE. They declined downstream to Whitecourt, where in 1989, the MWPL effluent raised river concentrations

notably. Concentrations declined downstream to about 0.005 mg/L near Athabasca and remained near that level down river. Concentrations in much of the river in 1989 did not comply with the ASWQO of 0.005 mg/L.

Tannin and lignin were very low in the headwaters (0.1 mg/L), increased to about 1.5 mg/L due to the HCE, then declined downstream and stabilized at about 0.6 mg/L near Smith. Tributary inflow to the lower river contained similar concentrations. Water quality guidelines have not been specified for tannin and lignin.

Diethylenetriaminepentaacetic acid (DTPA) and ethylenediamine-tetraacetic acid (EDTA) were present in the MWPL effluent, but were not detected in the rivers (<0.5 mg/L). No water quality guidelines exist for these compounds.

The trace organic 'priority pollutants' chloroform, 2,4,6-trichlorophenol, and toluene were detected in the Athabasca River at low ppb levels (within the CWQG) and likely originated from the HCE. A number of other base/neutral, phenol, fatty acid, and resin acid trace organic compounds were also detected in river water at ppb levels and were attributable to the HCE. These compounds are not 'priority pollutants' and are not addressed by the CWQG.

Organic carbon increased in concentration along the river system, due to the organic material discharged by the HCE and secondarily the MWPL effluent, and due to tributary inflow. No water quality objectives exist for organic carbon.

The Athabasca River upstream of Hinton was very low in colour. The HCE increased colour markedly, resulting in non-compliance with the ASWQO. Colour declined to about 20 to 30 relative units in the

Whitecourt vicinity and remained near that level in the rest of the river, partly due to the inflow of natural 'brown water' tributaries.

Odour of the water was evaluated on site in both winters. Odour was never detected upstream of Hinton, but the HCE imparted a distinct odour to the river water which in winter persisted at least as far downstream as Smith. All tributaries were sampled and they rarely had any discernible odour. Other individual effluents did not appear to affect river odour. Some odour persisted along the entire length of the river in 1989.

Nitrate (NO_3^--N) concentrations ranged from 0.055 mg/L to 0.206 mg/L, generally increasing from Hinton to Lake Athabasca as a result of tributary loading. Concentrations of ammonium (NH_4^+-N) also generally increased along the river, ranging from 0.01 to 0.08 mg/L. Slight increases in NH_4^+-N occurred downstream of Hinton and Whitecourt, due to loading from the HCE and McLeod River, respectively; a sharp increase occurred downstream of Ft. McMurray due to the Clearwater River and the Ft. McMurray STP. Organic nitrogen concentrations were 0.2 to 0.4 mg/L in most of the river with slight increases downstream of Hinton and Whitecourt due to loading from the HCE and MWPL effluent, respectively. Organic nitrogen was, on average, 65% of total nitrogen (TN). All reaches of the river were in compliance with the ASWQO for nitrogen fractions.

Total phosphorus (TP) upstream of Hinton was about 0.005-0.014 mg/L and was increased to about 0.030 mg/L due to the HCE. It declined to about 0.010 mg/L upstream of Whitecourt, where in 1989 the MWPL effluent increased river TP to about 0.05 mg/L. TP declined downstream

to about 0.02-0.03 mg/L near Ft. McMurray where the Clearwater River and the STP effluent doubled TP concentrations. On average, about 50% of TP in the river was dissolved. TP in the Whitecourt-Smith reach exceeded the ASWQO of 0.05 mg/L during one survey in 1989, due to the MWPL effluent.

Iron concentrations were about 0.1 to 0.2 mg/L in the river down to Ft. McMurray where they more than doubled due to the inflow of the Clearwater River and other tributaries. In that area, iron exceeded the ASWQO due to natural causes. Manganese increased from about 0.01 to 0.04 mg/L due to the HCE, and increased slightly due to the MWPL effluent. It tended to revert to 0.01 mg/L concentration in much of the river, except downstream of Ft. McMurray, where natural tributary inflow raised it to about 0.04 mg/L. Manganese generally complied with the ASWQO. Zinc was very high in pulp mill effluents, but no effect on river concentrations was apparent and zinc complied with the ASWQO. Aluminum, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Se, and V were not affected by effluent discharges and generally complied with the ASWQO or CWQG.

Upstream of Hinton, total coliform bacterial densities were 5 to 30/100 mL. They increased to a maximum of 140/100 mL immediately downstream of Hinton due to the HCE. Densities decreased downstream to Whitecourt. In the Ft. McMurray area, total coliforms increased somewhat due to input from the Ft. McMurray STP and the Clearwater River. Fecal coliform bacteria increased in density downstream of the HCE on one occasion, but not on others, and were generally low in number throughout the river (0 - 4/100mL). All measurements of fecal and total coliform bacteria in river samples complied with the ASWQO.

There were no effects on pH, hardness and fluoride concentrations due to effluent discharged to the river. The temperature of river water increased slightly due to the HCE and the MWPLE, and ice-free areas resulted. Alkalinity increased about 20 mg/L downstream of Whitecourt, due in part to the MWPLE.

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Appendix 1. Survey 88-1 water quality date.

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L	Na mg/L 11103L
AR ab. Hinton - Left	00AL07AD1080	0	1 2 88		0.1		11.54	8		390							
AR ab. Hinton - Centre	00AL07AD1085	0	1 2 88	25.1	0.1		11.74	8.05	8.03	425			136	239	64.8	18.7	2.3
AR ab. Hinton - Right	00AL07AD1090	0	1 2 88		0.1		11.79	8		420							
H.C.E. - grab	20AL07AD1000	1.9	2 2 88	0.926	24.5	6.3		7.4	7.16	1407	2320		125	440	146	18.2	290
					24.2	6.4		7.5	7.21	1420	2320		131	448	150	17.7	290
					24	6.1		7.5	7.08	1460	2320		125	446	149	17.9	299
									6.85				130	447	150	17.6	300
H.C.E. - comp.	20AL07AD1001	1.9	2 2 88														
AR 1 km ds HCE - L	00AL07AD1170	3	2 2 88		0.8		11.07	8.1		475							
AR 1 km ds HCE - C	00AL07AD1180	3	2 2 88		1.1		11.02	8.15		420							
AR 1 km ds HCE - R	00AL07AD1190	3	2 2 88		0.4		10.76	8.1		500							
AR 6 km ds HCE - L	00AL07AD1200	7.5	2 2 88		0.2		11.38	8.15		485							
AR 6 km ds HCE - R	00AL07AD1220	7.5	2 2 88		0.2		11.43	8.1	8.03	495			136	240	64.6	19	13.4
AR 11 km ds HCE -L	00AL07AD1270	12.9	2 2 88		0		11.33	8.15		485							
AR 11 km ds HCE -R	00AL07AD1290	12.9	2 2 88		0.2		11.38	8.15	8.03	495			135	232	62.6	18.3	13.5
AR 21 km ds HCE- L	00AL07AD1370	22.9	3 2 88		0		10.76	8		480							
AR 21 km ds HCE- C	00AL07AD1380	22.9	3 2 88		0		10.2	7.9		440							
AR 21 km ds HCE-L&R	00AL07AD1390	22.9	3 2 88		0		11.02	8		418							
AR 36 km ds HCE - L	00AL07AD1560	38.6	3 2 88		0		9.32	8		425							
AR 36 km ds HCE - C	00AL07AD1565	38.6	3 2 88		0	9.83	7.9	7.91		420			143	245	66.7	19	13.6
AR 36 km ds HCE - R	00AL07AD1570	38.6	3 2 88		0		10.35	7.95		460							
Oldman Creek	00AL07AD1700	55.7	3 2 88	0.908	0		13.18	8.3	7.34	382			212	215	63.2	13.9	4.8
AR 60 km ds HCE	00AL07AD1765	62.2	4 2 88		0		9.83	7.9		480							
AR above Berland - L	00AL07AD2050	103.8	4 2 88		0		9.37	7.8		440							
AR above Berland - C	00AL07AD2060	103.8	4 2 88		0		10.04	7.7	8.1	390			142	252	67.8	20.1	12.9
AR above Berland - R	00AL07AD2070	103.8	4 2 88		0		9.32	7.5		420							
Berland River	00AL07AC1000	104.2	4 2 88	6.43													
			5 2 88		0		10.56	7.85	8.22	440			231	240		16.7	8.2
AR 1.5 km ds Two Cr.	00AL07AE1260	160.5	5 2 88	48.6	0		9.94	7.9		480							
Windfall Creek	00AL07AE1290	166.9	4 2 88	0.49													
			5 2 88		0		12.51	7.7	8.05	290			167	162	48.3	10	10
AR above Whitecourt-L	00AL07AE1490	209.8	6 2 88		0		9.78	7.9		495							
AR above Whitecourt-C	00AL07AE1495	209.8	6 2 88		0		10.3	7.9	7.89	420			166	233	65.1	17	12
AR above Whitecourt-R	00AL07AE1500	209.8	6 2 88		0		9.17	7.8		490							
McLeod River-L	00AL07AG2050	211	6 2 88		0		6.02	7.5		610							
McLeod River-C	00AL07AG2060	211	6 2 88	3.69	0		5.46	7.5	8.02	590			326	294	83.5	20.7	31
McLeod River-R	00AL07AG2070	211	6 2 88		0		5.15	7.55		570							
AR 3 km ds McLeod-L	00AL07AH0650	214	6 2 88		0		9.27	7.75		431							
AR 3 km ds McLeod-C	00AL07AH0660	214	6 2 88		0		8.7	7.8		410							
AR 3 km ds McLeod-R	00AL07AH0670	214	6 2 88		0		9.17	7.7		421							
AR 10 km ds McLeod-L	00AL07AH1042	221.1	7 2 88		0		9.42	7.75		445							
AR 10 km ds McLeod-C	00AL07AH1044	221.1	7 2 88		0		10.25	7.8		479							
AR 10 km ds McLeod-R	00AL07AH1046	221.1	7 2 88		0		8.7	7.75		469							

Appendix 1. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L	Na mg/L 11103L
AR at Blue Ridge Br.-L	00AL07AH1080	236.2	7 2 88		0		8.7	7.7		510							
AR at Blue Ridge Br.-C	00AL07AH1085	236.2	7 2 88		0		9.01	7.7	8.08	450			183	244	68.5	17.7	14
AR at Blue Ridge Br.-R	00AL07AH1090	236.2	7 2 88		0		8.91	7.6		450							
AR at Ft. Assin. - L	00AL07AH1300	305.8	8 2 88		0		9.94	7.25		465							
AR at Ft. Assin. - C	00AL07AH1310	305.8	8 2 88		0		8.5	7.35	8.02	480			191	250	70	18.2	14.6
AR at Ft. Assin. - R	00AL07AH1320	305.8	8 2 88		0		8.7	7.4		495							
Freeman River	00AL07AH2000	306	8 2 88	0.118	0.1		8.65	7.1	8.03	1075			572		135	28.7	37.4
Pembina R.	00AL07BC0990	393.8	8 2 88		0		2.21	7.25	8.17	1010			579	462	125	36.3	55.6
AR above Smith - C	00AL07BD1000	437.5	9 2 88		0		8.76	7.65	8.17	465			194	254	70.1	19.2	15.2
AR above Smith - R	00AL07BD1020	437.5	9 2 88		0		8.08	7.65		500							
AR above Smith - L	00AL07BD1040	437.5	9 2 88		0		8.09	7.7		470							
L.S.R.-lake outflow	00AL07BK2100	-	9 2 88		0		10.31	7.6	7.78	270			115	121	35	8.2	10
L.S.R.-AR confluence	00AL07BK2150	449.4	9 2 88	12.3	0		13.03	7.9	7.92	258			99	104	30	7.1	8.9
AR n. of Howie L.-R	00AL07BE21000	511.1	10 2 88		0		9.32	7.85		390							
AR n. of Howie L.-L	00AL07BE2150	511.1	10 2 88		0		9.11	7.5		421							
AR n. of Howie L.-C	00AL07BE2200	511.1	10 2 88		0		8.96	7.65	7.64	385			177		61.5	15.5	14
AR at Athabasca-L	00AL07BE2300	556.4	11 2 88		0		8.7	7.7		420							
AR at Athabasca-C	00AL07BE2320	556.4	10 2 88	55													
		556.4	11 2 88		0		8.65	7.5	7.71	470			171	214	60.3	15.3	13.7
AR at Athabasca-R	00AL07BE2340	556.4	11 2 88		0		8.86	7.6		417							
Ar above Horse R.-L	00AL07CC0600	945.8	19 1 88		0.4	11.6		6.9	8.5	521	530	319	231	271	74	21	18
Clearwater R.	00AL07CD1200	950.6	19 1 88	35.6	0	12.2		6.9	7.6	383	393	203	69	81	21	7	50
AR near Bitumount-L	00AL07DA4200	1029	19 1 88		0.3	11.5		7.3	8	502	544	304	168	193	51	16	43
AR near Bitumount-R	00AL07DA4300	1029	19 1 88		0	11.8		7.2	8	514	534	295	167	192	52	15	40
AR at Old Fort	00AL07DD1000	1156.8	20 1 88		0	10.2		7.3	8.1	541	553	309	165	204	57	15	45
AR-Big Point Chan.	00AL07DD1800	1238.7	20 1 88		0	9.8		7.2	8.1	473	488	265	156	175	47	14	36
AR-Goose Is. Chan.	00AL07DD1700	1243.4	20 1 88		0.3	9.8		7.2	8.1	425	501	275	159	182	50	14	37

Appendix 1. Continued...

STATION	K mg/L 19103L	HCO3 mg/L 06202L	CO3 mg/L 06302L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SS mg/L 10401L	FILT. RESID. mg/L 10451L	TURB. NTU 02074L	APP. COLOUR RCU 02011L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD5D mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR ab. Hinton - Left								4			5		2.8				0.8	0.5
AR ab. Hinton - Centre	0.5	166	L1.	1	92		5.1	2	260	1.6	5		2.1				1.7	0.4
AR ab. Hinton - Right								6			5		1.6				2.5	0.6
H.C.E. - grab	8	152	L1.	576	193	0.2	9.1	69	1310	62		2500	54.4		59.7	73.3	41.3	110
	8.1	160	L1.	563	199	0.22	9.5	64	1310	55		2500	58.4		72.9	91.5	49.5	120
	8.1	152	L1.	559	197	0.22	9.6	44	1310	60		2500	52.8		81	87	42.9	125
H.C.E. - comp.	8	158	L1.	628	194	0.2	9.6	70	1380	67		2000	58.5		67.7	78.3	51.6	132
AR 1 km ds HCE - L								4			75		8.8				2.5	2.6
AR 1 km ds HCE - C								3			100		8.7	2.3			2.4	1.5
AR 1 km ds HCE - R								6			100		9.9				2.5	2
AR 6 km ds HCE - L								4			75		7.6				3.1	2.2
AR 6 km ds HCE - R	0.8	166	L1.	20.5	100		4.5	6	300	6.3	100		6.8	2.6			2.6	3.8
AR 11 km ds HCE -L								4					7.7				3	3.8
AR 11 km ds HCE -R	0.9	165	L1.	20.9	96		4.9	5	300	5.9	100		6.5	1.9			2.4	5.2
AR 21 km ds HCE- L								10			100		4.3	4.2			2.5	2.2
AR 21 km ds HCE- C								1					2.7	2.7			2.4	3.4
AR 21 km ds HCE-L&R								4			100		4.2				2.9	2
AR 36 km ds HCE - L								7					3.2				2.4	
AR 36 km ds HCE - C	0.9	174	L1.	20.2	97		5.4	10	300	10	100		3.7	2.2			2.2	1.2
AR 36 km ds HCE - R								LO.					3.7				2.3	
Oldman Creek	0.7	258	L1.	0.3	3.6		11.8	4	215	5.4	6.5		2.6				0.8	1.2
AR 60 km ds HCE								2			75		3.3				2.7	1.4
AR above Berland - L								LO.			75		1.7				0.5	3.6
AR above Berland - C	0.8	173	L1.	19.6	97		6.2		300	2.7	50		2.6	0.6			1.7	3.5
AR above Berland - R								1			50		1.7				0.8	2.8
Berland River		282	L1.				7.3	2	260	2.9	5		1.4				0.7	2
AR 1.5 km ds Two Cr.								LO.			50		L.0				0.6	3
Windfall Creek	0.8	204	L1.	0.3	5.8		15	3	180	6.1	30		0.7				0.4	3.4
AR above Whitecourt-L								2			50		2.9				1.1	3
AR above Whitecourt-C	0.8	202	L1.	14.5	73		6	3	280	3	50		1.1				1	2.2
AR above Whitecourt-R								2			75		1.9				0.8	2
McLeod River-L								LO.			10		1.1				0.8	4.2
McLeod River-C	1.6	397	L1.	2.1	18.2		11.1	1	355	2.1	10		1				0.3	4
McLeod River-R								1			10		0.8				0.4	4.2
AR 3 km ds McLeod-L								4										
AR 3 km ds McLeod-C								3										
AR 3 km ds McLeod-R								21										
AR at Blue Ridge Br.-L								2					2				0.7	
AR at Blue Ridge Br.-C	0.9	223	L1.	12.8	68		6.8		290	3	50		1.1				0.4	3
AR at Blue Ridge Br.-R								3					2.5				0.9	

Appendix 1. Continued...

STATION	K mg/L 19103L	HCO3 mg/L 06202L	CO3 mg/L 06302L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SS mg/L 10401L	FILT. RESID. mg/L 10451L	TURB. NTU 02074L	APP. COLOUR RCU 02011L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD5D mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR at Ft. Assin. - L								63					2.7				1.9	
AR at Ft. Assin. - C	1	233	L1.	13.9	66		7.1	19	300	18	50		2.3				1.6	3.4
AR at Ft. Assin. - R								2					1.7				1.3	
Freeman River	3.6	698	L1.	11.8	18.6		33.2	20	600	15	75		1				1.3	14.8
Pembina R.	4.3	706	L1.	5.1	33		14.3	2	610	6	40		1.1				0.9	14.6
AR above Smith - C	1	236	L1.	12.1	64		7.1	L0.	300	2.8	35		1.6				1.5	3.4
AR above Smith - R								2					2.3				1.8	
AR above Smith - L								3					1.6				1.3	
L.S.R.-lake outflow	3.5	140	L1.	1.7	17.1		1.7	3	145	4.6	40		1				1.5	12.8
L.S.R.-AR confluence	3	121	L1.	1.6	14.7		0.9	3	125	3.1	20		2.8				1.9	10
AR n. of Howie L.-R													2.7				2.3	
AR n. of Howie L.-L													4.5				3	
AR n. of Howie L.-C	1.5	216	L1.	9.2	49.6		5.6	1	260	3.8	30		3.6				2.8	5.2
AR at Athabasca-L								L0.										
AR at Athabasca-C	1.5	208	L1.	9.1	49.8		5.6	2	250	3								
AR at Athabasca-R								L0.										
Ar above Horse R.-L	1.5	262	10	8	58	0.15	7	3		1.4		24						6.3
Clearwater R.	1.1	84		72	11	0.11	13.4	L0.		1.6		21						4.4
AR near Bitumount-L	1.4	205		49	43	0.14	9.4	1		3		24						6.3
AR near Bitumount-R	1.4	204		46	40	0.14	9.7	1		2.3		21						6.1
AR at Old Fort	1.5	201		53	39	0.14	10.2	2		2.1		24						6.4
AR-Big Point Chan.	1.3	190		39	34	0.13	10.9	1		1.9		24						6
AR-Goose Is. Chan.	1.3	194		41	36	0.13	10.9	2		2.3		24						6.3

Appendix 1. Continued...

STATION	TOC mg/L 06005L	PC mg/L 06905L	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOT. NH3-N mg/L 07505L	DISS. NH3-N mg/L 07562L	TKN mg/L 07015L	TDP mg/L 15105L	TDP mg/L 15114L	TP mg/L 15421L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	STD.PL. COUNT #/mL 36905L	CHL-a ug/L 06715L
AR ab. Hinton - Left	0.6			L.001	0.1		0.098	0.01		0.35		0.0019		0.005	L1.	4	2000	
AR ab. Hinton - Centre	0.5			L.001	0.2		0.102	0.01		0.31		0.0017		0.0046	L1.	14	400	0.3
AR ab. Hinton - Right	0.8			L.001	0.1		0.101	0.01		0.3		0.0025		0.0062	L1.	50	100	
H.C.E. - grab	143		L1.	0.104	52.1	L.003	L.003	4.2		7.2	0.18		0.86					
	144		L1.	0.106	60	L.003	L.003	1.56		7.4	0.13		0.79		10			
	148		L1.	0.11	60	L.003	L.003	3.8		7.12	0.19		0.57					
H.C.E. - comp.	152		L1.	0.096	60.8	L.003	L.003	0.64		8.4	0.1		0.84					
AR 1 km ds HCE - L	3.6			0.005	1		0.1	0.02		0.48					L1.	120	25000	
AR 1 km ds HCE - C	4.4			0.006	1.3		0.077	0.03		0.46		0.0024		0.0322	L1.	158	20000	
AR 1 km ds HCE - R	5			0.005	1.5		0.097	0.02		0.52					L1.	140	30000	
AR 6 km ds HCE - L	4.3			0.005	1.5		0.107	0.03		0.48					L1.	144	20000	
AR 6 km ds HCE - R	4.8			0.004	1.3		0.106	0.03		0.59		0.0033		0.0312	L1.	136	30000	0.3
AR 11 km ds HCE -L	4.8			0.005	1.6										L1.	170	20000	
AR 11 km ds HCE -R	5.4			0.004	1.5		0.11	0.03		0.49		0.0037		0.032	L1.	110	35000	0.3
AR 21 km ds HCE- L	5			0.005	1.6										L1.	122	20000	
AR 21 km ds HCE- C	4.2			0.003	1.6		0.061	0.04		0.54		0.0057		0.0319	L1.	112	2000	0.4
AR 21 km ds HCE-L&R	4.5			0.004	1.3										L1.	182	7000	
AR 36 km ds HCE - C	4.2			0.003	1.5		0.108	0.04		0.4		0.0211		0.0355	L1.	20	6500	1.1
Oldman Creek	1.4				0.1		0.129	0.02		0.38		0.0109		0.0122	L1.	4	20	0.2
AR 60 km ds HCE	4.2			0.004	1.4		0.084	0.03		0.33					L1.	86	25000	
AR above Berland - L	3.8			0.002	1.5										L1.	8	20000	
AR above Berland - C	3.6			0.002	1.3		0.082	0.03		0.33		0.0047		0.0144	L1.	12	35000	0.2
AR above Berland - R	4.6			0.002	1.3										L1.	12	8000	
Berland R.	2.4			L.001	0.2		0.065	0.03		0.36		0.0031		0.0063				0.3
AR 1.5 km ds Two Cr.	3.2			0.003	0.9		0.062	0.03		0.42		0.0054		0.0111	L1.	L1.	4800	
Windfall Creek	3.6			0.002	0.2		0.061	0.02		0.31		0.0063		0.0215	L1.	L1.	300	0.5
AR above Whitecourt-L	3.6			L.001	0.8		0.062	0.03		0.4					L1.	2	4000	
AR above Whitecourt-C	2.8			0.002	0.9		0.07	0.02		0.32		0.0027		0.0087	L1.	6	14500	0.1
AR above Whitecourt-R	3.2			0.002	0.8		0.032	0.07		0.45					L1.	6	9200	
McLeod River-L	4.8			L.001	0.2		0.135	0.07		0.45					L1.	6	70	
McLeod River-C	4.4			L.001	0.2		0.193	0.07		0.57		0.0029		0.0058	L1.	2	40	0.2
McLeod River-R	4.4			L.001	0.2		0.189	0.06		0.47					L1.	L1.	30	
AR 3 km ds McLeod-L							0.119	0.04		0.38								
AR 3 km ds McLeod-C							0.069	0.05		0.43								
AR 3 km ds McLeod-R							0.144	0.07		0.49								
AR 10 km ds McLeod-L																58	5000	
AR 10 km ds McLeod-C																76	1000	
AR 10 km ds McLeod-R																72	4000	
AR at Blue Ridge Br.-L															L1.	24	3000	
AR at Blue Ridge Br.-C	3.2			L.001	0.8		0.116	0.03		0.3		0.0055		0.0109	L1.	30	4500	
AR at Blue Ridge Br.-R															L1.	16	11000	

Appendix 1. Continued...

STATION	TOC mg/L 06005L	PC mg/L 06905L	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOT. NH3-N mg/L 07505L	DISS. NH3-N mg/L 07562L	TKN mg/L 07015L	TDP mg/L 15105L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	STD.PL. COUNT #/mL 36905L	CHL-a ug/L 06715L
AR at Ft. Assin.- C	3.6			L.001	0.6		0.127	0.05		0.36		0.0071		0.0147	L1.	2	6000	2
Freeman River	16.5			L.001	0.8		0.031	0.08		0.77		0.0218		0.0281	L1.	L1.	3000	L1.
Pembina R.	16.2			L.001	0.7		0.069	0.06		0.63		0.0156		0.0275	L1.	L1.	200	0.7
AR above Smith - C	5			L.001	0.6		0.13	0.05		0.56		0.0039		0.0081	L1.	6	5000	0.2
L.S.R.-lake outflow	13.2			L.001	0.4		0.063	0.06		0.73		0.085		0.018	L1.	L1.	500	2.5
L.S.R.-AR confluence	10.8			L.001	0.3		0.02	0.02		0.42		0.0124		0.0211	L1.	42	480	1.1
AR n. of Howie L.-C	5.5			L.001	0.7		0.11	0.04		0.42		0.0067		0.0125	L1.	10	2000	0.5
AR at Athabasca-C							0.115	0.04		0.43		0.0069		0.0114	L1.	4	14000	
Ar above Horse R.-L		0.27	L.2	0.004	0.25	L.001	0.11		0.063	0.27		0.0072	0.009	0.0105	L4.	L4.		0.3
Clearwater R.		0.46	L.2	0.003	0.38	0.002	0.129		0.114	0.33		0.023	0.035	0.0361	L4.	L4.		0.6
AR near Bitumount-L		0.47	0.3	0.004	0.63	L.001	0.141		0.085	0.35		0.0155	0.025	0.0261	10	28		0.3
AR near Bitumount-R		0.48	L.2	0.004	0.52	L.001	0.132		0.089	0.31		0.0144	0.023	0.0259	4	8		0.3
AR at Old Fort		0.49	0.5	0.004	0.58	L.001	0.129		0.08	0.33		0.0124	0.025	0.0268	L4	4		0.3
AR-Big Point Chan.			0.5	0.004	0.53	L.001	0.119		0.079	0.32		0.013	0.024	0.0274	L4.	8		0.3
AR-Goose Is. Chan.			0.3	0.004	0.53	L.001	0.123		0.08	0.34		0.014	0.025	0.0285	L4.	4		0.3

Appendix 1. Continued.

STATION	TOTAL Al mg/L 13030L	TOTAL As mg/L 33011L	TOTAL Ba mg/L 56009L	DISS. Be mg/L 04103L	TOTAL Cd mg/L 48009L	TOTAL Co mg/L 27009L	TOTAL Cr mg/L 24009L	TOTAL Cu mg/L 29009L	TOTAL Fe mg/L 26009L	EXTR. Fe mg/L 26304L	TOTAL Hg mg/L 80015L	TOTAL Mn mg/L 25003L	TOTAL Mo mg/L 42009L	TOTAL Ni mg/L 28009L	EXTR. Pb mg/L 82302L	TOTAL Pb mg/L 82002L
AR ab. Hinton - Centre	0.09								0.1			0.007				
H.C.E. - grab		0.0002			L.001					0.5	L.05 1L				0.006	
		L.0002			L.001					0.5	L.05 1L				0.012	
		0.0002			L.001					0.51	L.05 1L				0.005	
H.C.E. - comp.		L.0002			L.001		0.006	0.009		0.48	L.05 1L	1	0.021	L.001		0.004
AR 6 km ds HCE - R	L.01								0.08			0.043				
AR 21 km ds HCE- C	0.05								0.15			0.044				
Oldman Creek	0.04								0.1			0.008				
AR above Berland - C	0.02								0.06			0.008				
Berland River	0.04								0.16			0.007				
Windfall Creek	0.06								1.05			0.15				
AR above Whitecourt-C	0.06								0.09			0.007				
McLeod River-C	0.04								0.06			0.007				
AR at Ft. Assin. - C	0.08								0.13			0.01				
Freeman River	0.09								0.08			0.65				
Pembina R.	0.03								0.27			0.13				
AR above Smith - C	0.04								0.13			0.007				
L.S.R.-lake outflow	0.05								0.37			0.21				
L.S.R.-AR confluence	0.06								0.21			0.061				
AR at Athabasca-C	0.04								0.12			0.006				
Ar above Horse R.-L	0.036	0.0005	0.122	L.001	0.003	0.004	0.006	0.007		0.13	L.0001	L.008	0.007	0.009	L.003	
Clearwater R.	0.054	0.0004	0.022	L.001	L.001	0.002	0.002	0.003		0.6	L.0001	0.034	0.002	0.005	L.003	
AR near Bitumount-L	0.048	0.0004	0.081	L.001	0.002	0.003	0.004	0.004		0.35	L.0001	0.025	0.004	0.008	L.003	
AR near Bitumount-R	0.042	0.0004	0.084	L.001	0.002	0.003	0.003	0.003		0.33	L.0001	0.024	0.004	0.007	L.003	
AR at Old Fort	0.044	0.0008	0.079	L.001	0.002	0.002	0.005	0.003		C 46	L.0001	0.055	0.002	0.005	L.003	
AR-Big Point Chan.	0.044	0.0006	0.053	L.001	0.002	0.007	0.014	0.005		0.43	L.0001	0.044	0.002	0.007	L.003	
AR-Goose Is. Chan.	0.037	0.0007	0.071	L.001	0.002	0.002	0.005	0.003		0.4	L.0001	0.045	L.001	0.005	L.003	

Appendix 1. Continued...

STATION	TOTAL Se mg/L 34011L	TOTAL V mg/L 23009L	TOTAL Zn mg/L 30009L	CN mg/L 06608L	TOTAL Ag mg/L 47005L
AR ab. Hinton - Centre			0.005	L.001	
H.C.E. - grab	L.0002				
	L.0002				
	L.0002				
H.C.E. - comp.	L.0002	0.015	0.088		L.001
AR 6 km ds HCE - R			0.003	L.001	
AR 11 km ds HCE -R				L.001	
AR 21 km ds HCE- C			0.017		
AR 36 km ds HCE - C				L.001	
Oldman Creek			0.001	L.001	
AR above Berland - C			0.002	L.001	
Berland River			0.12	L.001	
Windfall Creek			0.001		
AR above Whitecourt-C			0.004	L.001	
McLeod River-C			0.003	L.001	
AR at Ft. Assin. - C			0.005	L.001	
Freeman River			0.009	L.001	
Pembina R.			0.016		
AR above Smith - C			0.001	L.001	
L.S.R.-lake outflow			0.011	L.001	
L.S.R.-AR confluence			0.001	L.001	
AR n. of Howie L.-C				L.001	
AR at Athabasca-C			0.008	L.001	
Ar above Horse R.-L	L.0002	0.009	0.005		
Clearwater R.	L.0002	0.004	0.033		
AR near Bitumount-L	L.0002	0.007	0.081		
AR near Bitumount-R	L.0002	0.007	0.013		
AR at Old Fort	L.0002	0.005	0.004		
AR-Big Point Chan.	L.0002	0.011	L.001		
AR-Goose Is. Chan.	0.0008	0.005	0.003		

Appendix 2. Survey 88-2 water quality data.

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR ab. Hinton - Left	00AL07AD1080	0	4 3 88		0		11.57									
AR ab. Hinton - Centre	00AL07AD1085	0	3 3 88	31.4												
			4 3 88		0		11.42									
AR ab. Hinton - Right	00AL07AD1090	0	4 3 88		0		11.77									
H.C.E. - grab	20AL07AD1000	1.9	4 3 88	0.973	26.5	5.8		7								
			5 3 88		26.4	5.5		7								
					26.2	5.4		7.1		2190						
H.C.E. - comp.	20AL07AD1001	1.9	4 3 88													
AR 1 km ds HCE - L	00AL07AD1170	3	4 3 88		0.7		11.47									
AR 1 km ds HCE - C	00AL07AD1180	3	4 3 88		0.9		11.57									
AR 1 km ds HCE - R	00AL07AD1190	3	4 3 88		1.7		10.96									
AR 6 km ds HCE - L	00AL07AD1200	7.5	5 3 88		0.2		11.27									
AR 6 km ds HCE - R	00AL07AD1220	7.5	5 3 88		0.8		11.01									
AR 11 km ds HCE -L	00AL07AD1270	12.9	5 3 88		0.3		10.15									
AR 11 km ds HCE -C	00AL07AD1280	12.9	5 3 88		0.4		11.16									
AR 11 km ds HCE -R	00AL07AD1290	12.9	5 3 88		0.4		11.16									
AR 21 km ds HCE- L	00AL07AD1370	22.9	5 3 88		0.1		10.15									
AR 21 km ds HCE-L&R	00AL07AD1390	22.9	5 3 88		0.1		11.37									
AR 36 km ds HCE - L	00AL07AD1560	38.6	5 3 88		0		10.81									
AR 36 km ds HCE - C	00AL07AD1565	38.6	5 3 88		0		10.91									
AR 36 km ds HCE - R	00AL07AD1570	38.6	5 3 88		0		10.2									
Oldman Creek	00AL07AD1700	55.7	5 3 88	1.33	0		12.38									
AR 60 km ds HCE	00AL07AD1765	62.2	5 3 88		0		10.45									
AR above Berland - L	00AL07AD2050	103.8	5 3 88		0		9.74									
AR above Berland - C	00AL07AD2060	103.8	5 3 88		0		10.15									
AR above Berland - R	00AL07AD2070	103.8	5 3 88		0		10.35									
Berland River	00AL07AC1000	104.2	4 3 88	7.69												
			5 3 88		0		10.66									
AR 1.5 km ds Two Cr.	00AL07AE1260	160.5	6 3 88		0		9.74									
			7 3 88	51.1												
Windfall Creek	00AL07AE1290	166.9	6 3 88		0		11.47									
			7 3 88	0.479												
AR above Whitecourt-L	00AL07AE1490	209.8	6 3 88		0		9.74									
AR above Whitecourt-C	00AL07AE1495	209.8	6 3 88		0		9.64									
AR above Whitecourt-R	00AL07AE1500	209.8	6 3 88		0		9.64									
McLeod River-L	00AL07AG2050	211	6 3 88		0		9.74									
McLeod River-C	00AL07AG2060	211	6 3 88		0		9.64									
			7 3 88	7.5												
McLeod River-R	00AL07AG2070	211	6 3 88		0		9.74									
AR 3 km ds McLeod-L	00AL07AH0650	214	7 3 88		0		9.29									
AR 3 km ds McLeod-C	00AL07AH0660	214	7 3 88		0		9.49									
AR 3 km ds McLeod-R	00AL07AH0670	214	7 3 88		0		9.44									

Appendix 2. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR at Blue Ridge Br.-L	00AL07AH1080	236.2	7 3 88		0		9.59									
AR at Blue Ridge Br.-C	00AL07AH1085	236.2	7 3 88		0		9.59									
AR at Blue Ridge Br.-R	00AL07AH1090	236.2	7 3 88		0		9.39									
AR at Ft. Assin. - L	00AL07AH1300	305.8	7 3 88		0		9.74									
AR at Ft. Assin. - C	00AL07AH1310	305.8	7 3 88		0		9.59									
AR at Ft. Assin. - R	00AL07AH1320	305.8	7 3 88		0		9.59									
Freeman River	00AL07AH2000	306	7 3 88		0		8.98									
			8 3 88	0.151												
Pembina R.	00AL07BC0990	393.8	7 3 88	1.37	0		7.81									
AR above Smith - C	00AL07BD1000	437.5	8 3 88		0		9.08									
AR above Smith - R	00AL07BD1020	437.5	8 3 88		0		8.98									
AR above Smith - L	00AL07BD1040	437.5	8 3 88		0		9.08									
L.S.R.-lake outflow	00AL07BK2105	-	8 3 88		2.6		13.75									
L.S.R.-AR confluence	00AL07BK2150	449.4	3 3 88	12.6												
			8 3 88		0		11.17									
AR n. of Howie L.-R	00AL07BE2100	511.1	9 3 88		0		9.18									
AR n. of Howie L.-L	00AL07BE2150	511.1	9 3 88		0		9.99									
AR n. of Howie L.-C	00AL07BE2200	511.1	9 3 88		0		9.18									
AR at Athabasca-L	00AL07BE2300	556.4	9 3 88		0		9.79									
AR at Athabasca-C	00AL07BE2320	556.4	9 3 88	72.6	0		9.44									
AR at Athabasca-R	00AL07BE2340	556.4	9 3 88		0		9.44									
Ar above Horse R.-L	00AL07CC0600	945.8	17 3 88		0	13.6		7.2	8	482	450	258	171	210	56	17
Clearwater R.	00AL07CD1200	950.6	17 3 88	42.3	0.1	12.9		6.7	7.6	408	378	188	75	74	18	7
Ft. McMurray STP	21AL07DA1000	950.6	16 3 88	0.15	1.5				7.6		1086	577	345	252	64	20
AR ab Suncor-L	00AL07DA0980	978.2	15 3 88		0	12.4		6.6	7.9	495	463	260	171	198	53	16
Suncor Process Eff.	20AL07DA1001	981	15 3 88	0.3				7.9	7.5		515	539	95	246	69	18
AR near Bitumount-L	00AL07DA4200	1029	15 3 88		0	12.2		6.8	8.1	502	467	246	148	175	47	14
AR near Bitumount-R	00AL07DA4300	1029	15 3 88		0	12		6.7	7.9	492	457	248	141	170	45	14
AR at Old Fort	00AL07DD1000	1156.8	16 3 88		0	11.2		6.9	8	530	490	266	145	177	48	14
AR-Big Point Chan.	00AL07DD1800	1238.7	16 3 88		0	10.5		6.6	7.9	475	442	238	134	161	43	13
AR-Goose Is. Chan.	00AL07DD1700	1234.4	16 3 88		0.1	10.6		6.2	7.7	424	453	247	138	163	44	13

Appendix 2. Continued...

STATION	Na mg/L 11103L	K mg/L 19103L	HCO3 mg/L 06202L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SS mg/L 10401L	TURB. NTU 02074L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD5D mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR ab. Hinton - Left										5	1.4					
AR ab. Hinton - Centre										L5.	1.6	1.4				
AR ab. Hinton - Right										5	1.5					
H.C.E. - grab										1000	39		42.6	46.8	26	
										1000	28.6		46.8	70.2	27.8	
										1000	37.5		52.2	96	35.4	
										1000	21.8		25.8	51	19.9	
H.C.E. - comp.										30	2.3					
AR 1 km ds HCE - L										60	2.8	1.6				
AR 1 km ds HCE - C										100	3.7					
AR 1 km ds HCE - R										50	2.2					
AR 6 km ds HCE - L										100	2.7	1.6				
AR 6 km ds HCE - R										60	2.5					
AR 11 km ds HCE -L										75	2.3	1.4				
AR 11 km ds HCE -C										100	2.5					
AR 11 km ds HCE -R										60	2.7					
AR 21 km ds HCE- L										60	2.6					
AR 21 km ds HCE-L&R										100	2.6					
AR 36 km ds HCE - L										75	2.3	1.3				
AR 36 km ds HCE - C										50	2.3					
AR 36 km ds HCE - R										5	2.2					
Oldman Creek										50	2.1					
AR 60 km ds HCE										40	1.8					
AR above Berland - L										50	1.9	1.1				
AR above Berland - C										50	1.6					
AR above Berland - R										5	1.2					
Berland River										40	2.4					
AR 1.5 km ds Two Cr.										20	2					
Windfall Creek										30	2.4					
AR above Whitecourt-L										30	1.9					
AR above Whitecourt-C										40	2.2					
AR above Whitecourt-R										10	2.1					
McLeod River-L										10	1.9					
McLeod River-C										10	2					
McLeod River-R										30						
AR 3 km ds McLeod-L										35						
AR 3 km ds McLeod-C										30						
AR 3 km ds McLeod-R										40	1.2					
AR at Blue Ridge Br.-L										35	1.3					
AR at Blue Ridge Br.-C										30	1.6					
AR at Blue Ridge Br.-R																

Appendix 2. Continued...

STATION	Na mg/L 11103L	K mg/L 19103L	HCO3 mg/L 06202L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SS mg/L 10401L	TURB. NTU 02074L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD5D mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR at Ft. Assin. - L										30	1					
AR at Ft. Assin. - C										30	1.5					
AR at Ft. Assin. - R										35	1.7					
Freeman River										20	1.4					
Pembina R.										30	1.5					
AR above Smith - C										30	0.9					
AR above Smith - R										30	1.2					
AR above Smith - L										30	0.9					
L.S.R.-lake outflow										12.5	1.3					
L.S.R.-AR confluence										20	1.2					
AR n. of Howie L.-R										20	2.2					
AR n. of Howie L.-L										30	1.4					
AR n. of Howie L.-C										30	1.6					
AR at Athabasca-C										10						
Ar above Horse R.-L	17	1.2	208	9	55	0.13	5	1	2.7	12.8						6.7
Clearwater R.	45	1	91	63	9	0.12	13.5	4	4.1	9.2						4.2
Ft. McMurray STP	100	9.9	421	86	86	0.78	11	8	6.2	37.4					81	20.6
AR ab Suncor-L	22	1.4	208	15	50	0.13	5.5	3	1.5	20.1						6.5
Suncor Process Eff.	114	2.8	196	150	89	1.7	6.3	8	11	17.7					42	7.8
AR near Bitumount-L	32	1.2	180	33	30	0.13	7.5	2	3.7	20						6.3
AR near Bitumount-R	32	1.2	172	35	36	0.13	8	2	3.1	15.4						5.7
AR at Old Fort	36	1.2	177	43	37	0.13	9.4	3	4.1	17.5						6.5
AR-Big Point Chan.	31	1.1	163	37	32	0.12	10.3	1	3.5	18						
AR-Goose Is. Chan.	33	1.1	168	39	34	0.12	10.3	2	3.5	14.5						6

Appendix 2. Continued...

STATION	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOTAL NH3-N mg/L 07505L	DISS. NH3-N mg/L 07562L	TKN mg/L 07015L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	FECAL STREP. #/dL 36102L	CHL-a ug/L 06715L
AR ab. Hinton - Left					0.068	L.01		0.2							
AR ab. Hinton - Centre					0.067	L.01		0.2							
AR ab. Hinton - Right					0.066	L.01		0.24							
H.C.E. - grab				0.06	0.09	0.32		6.6							
				0.05	0.09	0.27		6.5							
				0.06	0.08	0.17		6.4							
H.C.E. - comp.				0.05	0.08	0.38		6.4							
AR 1 km ds HCE - L					0.066	L.01		0.3							
AR 1 km ds HCE - C					0.063	0.01		0.36							
AR 1 km ds HCE - R					0.062	0.13		0.5							
AR 6 km ds HCE - L					0.064	0.09		0.32							
AR 6 km ds HCE - R					0.066	0.01		0.44							
AR 11 km ds HCE -C					0.065	0.01		0.52							
AR 21 km ds HCE-L&R					0.072	0.01		0.36							
AR 36 km ds HCE - C					0.071	0.02		0.4							
Oldman Creek		0.011			0.107	L.01		0.24							
AR 60 km ds HCE					0.079	0.03		0.4							
AR above Berland - C					0.089	0.04		0.32							
Berland River					0.053	L.01		0.18							
AR 1.5 km ds Two Cr.					0.09	0.04		0.82							
Windfall Creek					0.071	0.02		0.3							
AR above Whitecourt-L					0.099	0.05		0.4							
AR above Whitecourt-C					0.092	0.06		0.8							
AR above Whitecourt-R					0.093	0.03		0.5							
McLeod River-L					0.26	L.01		0.38							
McLeod River-C					0.26	0.01		0.32							
McLeod River-R					0.27	0.08		0.5							
AR 3 km ds McLeod-L					0.089	0.04		0.62							
AR 3 km ds McLeod-C					0.13	0.05		0.48							
AR 3 km ds McLeod-R					0.135	0.05		0.36							
AR at Blue Ridge Br.-C					0.116	0.04		0.28							
AR at Ft. Assin. - C					0.121	0.04		0.42							
Freeman River					0.034	0.02		0.42							
Pembina R.					0.009	0.01		0.54							
AR above Smith - C					0.126	0.02		0.28							
L.S.R.-lake outflow					0.007	0.02		0.5							
L.S.R.-AR confluence					0.034	0.07		0.64							
AR n. of Howie L.-C					0.11	0.03		0.36							
AR at Athabasca-C					0.174	0.13		0.52							

Appendix 2. Continued...

STATION	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOTAL NH3-N mg/L 07505L	DISS. NH3-N mg/L 07562L	TKN mg/L 07015L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	FECAL STREP. #/dL 36102L	CHL-a ug/L 06715L
Ar above Horse R.-L	0.3	0.003	0.66	0.002	0.151		0.041	0.3	0.0066	0.012	0.013	L4.	40	64	0.7
Clearwater R.	0.2	0.003	0.41	0.003	0.192		0.083	0.34	0.025	0.044	0.047	L4.	76	L4.	0.8
Ft. McMurray STP	1.6	0.019	1.76	0.038	0.05		25.1	28.2	3.18	3.89		4600	7900	770	
AR ab Suncor-L	0.6	0.004	0.75	0.002	0.181		0.118	0.38	0.0199	0.025	0.0293	L4.	96	L4.	0.5
Suncor Process Eff.	3.7	0.01	0.9	0.012	0.03		0.237	0.902	0.128	0.254					
AR near Bitumount-L	0.2	0.003	0.57	0.002	0.199		0.104	0.34	0.0155	0.025	0.0294	L4.	124	4	0.5
AR near Bitumount-R	0.3	0.003	0.48	0.002	0.192		0.078	0.31	0.016	0.02	0.0288	L4.	96	4	0.5
AR at Old Fort	0.4	0.003	0.57	0.002	0.188		0.108	0.31	0.0156	0.027	0.0307	L4.	80	4	0.4
AR-Big Point Chan.	0.3	0.003	0.5	0.002	0.172		0.081	0.31	0.0144	0.026	0.029	12	80	4	0.3
AR-Goose Is. Chan.	0.4	0.003	0.51	0.002	0.186		0.089	0.29	0.0157	0.027	0.0298	L4.	68	L4.	0.3

STATION	TOTAL Al mg/L 13030L	TOTAL As mg/L 33011L	TOTAL Ba mg/L 56009L	DISS. Be mg/L 04103L	TOTAL Cd mg/L 48009L	TOTAL Co mg/L 27009L	TOTAL Cr mg/L 24009L	TOTAL Cu mg/L 29009L	TOTAL Fe mg/L 26009L	TOTAL Hg mg/L 80015L	TOTAL Mn mg/L 25003L	TOTAL Mo mg/L 42009L	TOTAL Ni mg/L 28009L	EXTR. Pb mg/L 82302L	TOTAL Se mg/L 34011L	TOTAL V mg/L 23009L	TOTAL Zn mg/L 30009L
Ar above Horse R.-L	0.026	0.0004	0.084	L.001	0.002	L.001	0.004	0.002	0.15	L.0001	L.008	0.002	0.004	L.003	L.0002	0.003	0.002
Clearwater R.	0.034	0.0004	0.019	L.001	L.001	L.001	0.002	L.001	0.75	L.0001	0.028	L.001	0.002	L.003	L.0002	L.002	L.001
Ft. McMurray STP	0.103	0.0008	0.026	L.001	0.002	L.001	0.009	0.005		L.0001	0.051	0.004	0.006	0.004	L.0002	0.003	0.029
AR ab Suncor-L	0.037	0.0003	0.084	L.001	0.002	L.001	0.004	L.001	0.18	L.0001	0.014	0.002	0.004	L.003	L.0002	0.003	0.002
Suncor Process Eff.	0.103	0.002	0.101	L.001	0.002	0.002	0.005	0.007		L.0001	0.046	0.101	0.016	L.003	L.0002	0.053	0.008
AR near Bitumount-L	0.037	0.0004	0.061	L.001	0.002	L.001	0.003	L.001	0.38	L.0001	0.014	0.002	0.008	L.003	L.0002	L.002	0.002
AR near Bitumount-R	0.037	0.0003	0.064	L.001	0.002	L.001	0.003	L.001	0.39	L.0001	0.015	0.002	0.004	L.003	L.0002	0.003	0.002
AR at Old Fort	0.034	0.0005	0.064	L.001	L.001	L.001	0.003	L.001	0.51	L.0001	0.032	L.001	0.002	L.003	L.0002	L.002	L.001
AR-Big Point Chan.	0.024	0.0003	0.056	L.001	L.001	L.001	0.003	L.001	0.52	L.0001	0.028	L.001	0.005	L.003	L.0002	L.002	L.001
AR-Goose Is. Chan.	0.024	0.0003	0.058	L.001	L.001	L.001	0.002	L.001	0.47	L.0001	0.028	L.001	0.002	L.003	L.0002	L.002	L.001

Appendix 3. Survey 89-1 water quality data.

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR ab. Hinton	00AL07AD1085	0	9 1 89		0.2	12	11.7	7.3	8.02	391	408	236	125	207	55	17
							11.7		8.08		406	239	125	210	56	17
							11.56		8.1		403	233	124	207	55	17
			10 1 89	31.3												
Hinton Comb. Effl.	20AL07AD1001	1.9	9 1 89	0.97					5.22		1960	1089	10	340	105	19
AR 1 km ds HCE	00AL07AD1180	3	9 1 89		0.2	11.6	11.5	7.2		443						
							11.4									
AR 6 km ds HCE (left)	00AL07AD1200	7.5	9 1 89		0.5	11.5	11.2	8.1		428						
							11.2									
AR 6 km ds HCE (right)	00AL07AD1220	7.5	9 1 89		0	11.7	11.42	8.1		430						
							11.36									
AR 6 km ds HCE (comp)	00AL07AD1225	7.5	9 1 89													
AR 11 km ds HCE	00AL07AD1280	12.9	9 1 89		-0.3	11.6	11.05	8.2		434						
							11.08									
							11.01									
AR 21 km ds HCE	00AL07AD1380	22.9	9 1 89		-0.4	11.3	10.93	7.3		372						
							10.99									
							11									
AR 36 km ds HCE	00AL07AD1565	38.6	9 1 89		-0.4		11.16	7.4		374						
							10.79									
							10.76									
Oldman Creek	00AL07AD1700	55.7	10 1 89		0.7	13	12.25	8.3		369						
				0.7			12.47									
AR 60 km ds HCE	00AL07AD1765	62.2	10 1 89		0.1	11.4	11.03	8.2		423						
							10.84									
							10.74									
Spring 1	00AL07AD2001	78.4	10 1 89		4.6	11.8	12.23	8		407						
				0.015			11.03									
AR ab. Berland	00AL07AD2060	103.8	10 1 89		0	11.8	10.69	8.1	7.96	421	444	258	129	215	58	17
							10.5									
							10.6									
Berland River	00AL07AC1000	104.2	10 1 89	5.67	-0.2	9	8.57	7.9		440						
							8.7									
							8.56									
AR below Berland	00AL07AE0800	105	10 1 89	37.6												
Spring 2	00AL07AE0501	119	11 1 89	0.02	2.4	11.7		8.4		441						
Marsh Head Creek	00AL07AE0900	131.7	11 1 89		0.4	10.5	10.5	7.9		559						
				0.066			10.42									
Pine Creek	00AL07AE1050	131.9	11 1 89	0.019	0	10.7	10.51	7.6		399						
Spring 3	00AL07AE1141	149.7	11 1 89		1.3	10.8	10.68	7.9		383						
				0.015			10.79									

Appendix 3. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
Two Creek	00AL07AE1230	158.9	11 1 89	0.01	-0.3	8.4	7.61 7.73	7.8		651						
AR 1.5 km ds Two Cr.	00AL07AE1260	160.5	11 1 89		-0.4	10.5	10.23 10.54 10.36	7.9		434						
Windfall Creek	00AL07AE1290	166.9	11 1 89	0.000	-0.4	9.2	8.92 9.32	7.5		377						
AR at Windfall Bridge	00AL07AE1350	177.1	11 1 89	42.1												
AR ab. Whitecourt	00AL07AE1495	209.8	12 1 89		-0.2	11	10.31 10.37 10.44	8	7.87	436	456	259	153	224	60	18
McLeod River	00AL07AG2060	211	12 1 89		-0.3	5.3	5.28 5.23 5.32	7.8	7.76	501	576	328	296	268	76	19
Millar Western Effl.	20AL07AH1001	211.5	12 1 89	4.76 0.141					7.95		3560	2519	1239	335	75	36
AR 3 km ds McLeod	00AL07AH0660	214	12 1 89		0.2	9.6	9.91 10.14 10.05	7.9		391						
Whitecourt STP(grab)	21AL07AH0200	214.9	12 1 89				3.08 3.22		7.52		1042	574	353	294	83	21
AR 10 km ds McLeod	00AL07AH1044	221.1	12 1 89		-0.1	9.5	9.35 8.6 8.77	7.9		459						
AR at Blue Ridge Br.	00AL07AH1085	236.2	12 1 89		-0.2	9	8.66 8.88 8.75	7.9	7.79	463	485	275	174	231	63	18
AR ds Five Mile Is.	00AL07AH1150	274.4	12 1 89		-0.3	8.5	8.58 8.67 8.54	7.9		470						
AR at Ft. Assin. (ab. Freeman R.)	00AL07AH1310	305.8	16 1 89		0.1	7.6	7.54 7.76 7.64	7.8	7.81	461	485	282	176	235	66	17
Freeman River	00AL07AH2000	306	16 1 89		0.8	4.2	6.51 4.9 5.28	7.6		526						
AR above Pembina R.	00AL07BD0500	393.4	17 1 89 16 1 89	0.48	-0.2	8.3	7.98 8.11 8.04	7.8	7.9	481	505	292	183	246	69	18

Appendix 3. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
Pembina R.	00AL07BC0990	393.8	16 1 89		0	2.7	2.59 2.87 2.85	7.7		644						
AR above Smith (at Hwy. 2)	00AL07BD1000	437.5	17 1 89 18 1 89	2.8	0.1	7.4	7.58 7.65 7.74	7.8	8.08	484	511	294	192	241	65	19
L. Slave R. (at lake outflow)	00AL07BK2100	-	17 1 89		0.8	13.4	13.11 13.08	8.3		203						
Slave Lake STP (grab)	21AL07BK5000	-	18 1 89 17 1 89	25.1			7.29 7.19									
L. Slave R. (at Mitsue Br.)	00AL07BK2110	-	17 1 89		0.2	13.6	13.28 13.25	8.1		198						
L. Slave R. (ab. Driftwood R.)	00AL07BK2130	-	17 1 89		0	13.8	12.91 13.03 13.02	7.9		204						
L. Slave R. (at AR confluence)	00AL07BK2150	449.4	18 1 89		0	12.5	12.34 12.18	8	7.95	204	222	115	99	88	25	6.2
AR north of Howie L.	00AL07BE2200	511.1	20 1 89		0.7	8.6	8.85 8.89 8.88	7.8		394						
AR at Athabasca	00AL07BE2320	556.4	19 1 89	85.3	0	8.8	8.67 8.94 8.86	7.8	8	410	435	247	170	204	57	15
T. Athabasca STP (grab)	21AL07CB0100	557.4	20 1 89	0.012			1.79 1.26									
AR ab. La Biche R.	00AL07CB2410	617.4	25 1 89		0.1	8	8.13 8.22 8.22 8.21	7.7		402						
La Biche R.	00AL07CA1500	617.8	25 1 89	0.927	0.2		1.45 1.46	7.3		434						
Calling R.	00AL07CB2500	633.3	25 1 89	0.006	0.1	11	10.64 10.92	7.6		418						
AR near McMillan L.	00AL07CB3300	677.9	25 1 89		0.1	8	8.21 8.05 8.16	7.6		410						

Appendix 3. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR ab. Pelican R.	00AL07CB3800	740.4	25 1 89		0	8.2	8.18 8.64 8.18	7.7		413						
Pelican R.	00AL07CB3900	742.1	25 1 89	0.46	0	13.5	12.51 12.55	7.4		179						
AR ab. House R.	00AL07CB4150	799.9	8 2 89		0	7.1	7.52 7.45	7.5	7.07	399	426	238	162	189	51	15
House R.	00AL07CB4500	800.4	8 2 89		-0.5	10.4	10.55 10.74	7.3		480						
AR ab. Grand Rapids	00AL07CC2050	807.6	8 2 89		-0.4	7.2	7.21 7.84	7.5		408						
AR ab. Buffalo Cr.	00AL07CC3050	844.9	8 2 89		-0.4	12.5	12.41 12.15 12.18	7.6		410						
AR ab. Boiler Rapids	00AL07CC4050	887.5	8 2 89		-0.4	11.9	12 12 11.88	7.6		411						
AR ab. Horse R.	C0AL07CC0600	945.8	8 2 89		-0.4	12.5	11.91 12.22	7.6	7.87	414	438	247	169	192	52	15
Horse River	00AL07CC0750	947.3	8 2 89	0.389	-0.4	13.5	13.24 13.17	7.7		581						
Clearwater River	00AL07CD1200	950.6	8 2 89 9 2 89	49.2	-0.2	12.3	12.39	7.3	7.76	317	341	174	72	71	18	6.4
Ft. McMurray STP	21AL07DA1000	950.5		0.219												
AR ab. Suncor	00AL07DA0985	978.2	9 2 89		0	12.2	11.78 12	7.5		395						
Suncor Proc. Effl.	20AL07DA1000	981		0.289												
Steepbank River	00AL07DA1200	983.1	7 2 89 9 2 89	0.298	-0.2	13.8	13.14 13.39	8		474						
Muskeg River	00AL07DA2650	998.9	14 2 89		0.5	11.1	10.49 10.67	6.8		461						
Mackay River	00AL07DB1050	1002.8	14 2 89		0	12.6	11.98 12.13	7.3		576						
Ells River	00AL07DA3350	1020.2	14 2 89		-0.1	13.2	12.96 12.94	7		285						

Appendix 3. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR near Bitumount	00AL07DA4250	1029	14 2 89		0	11.8	11.71 11.9 11.93	6.9		416						
AR ab. Firebag R.	00AL07DA5050	1072	14 2 89		0	11.6	11.38 11.61 11.46	6.8		450						
Firebag River	00AL07DC0900	1075.7	13 2 89 14 2 89	9.33	-0.1	5.9	6.22 5.7 5.2	6.8		244						
AR at Old Fort	00AL07DD0900	1156.8	15 2 89		0.4	10.7	10.4 10.31 10.33	7.2	7.68	459	477	260	138	162	45	12
Richardson River	00AL07DD1140	1188.2	13 2 89 15 2 89	10.6	-0.2	5.9	5.35 6.48	6		94						
AR - Big Point Chan. (at mouth)	00AL07DD1800	1238.7	14 2 89 15 2 89	81.1	-0.2	10.7	9.64 10.62 9.85	7.3		401						
AR - Goose Is. Chan. (at mouth)	00AL07DD1700	1243.4	14 2 89 15 2 89	67.4			10.2 10.26 10.46									

Appendix 3. Continued...

STATION	Na mg/L 11103L	K mg/L 19103L	HCO3 mg/L 06202L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SULFIDE mg/L 16200L	SS mg/L 10401L	TURB. NTU 02074L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD5D mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR above Hinton	3	0.5	152	0.9	84	0.14	4.5	0.002	2	2	1	L.1				6	0.4
	3	0.5	152	0.9	86	0.14	4.5		4	2	1	1	L.5	1.7	1.9	L4.0	0.4
	2	0.5	151	0.9	83	0.13	4.4	0.002	3	1.7	1	1.4				4	0.4
Hinton comb. effl.	275	7.1	12	436	241	0.2	8.6	0.169	42	35	1270	30	16	53	62	392	106
AR 1 km ds HCE												2.1					
AR 6 km ds HCE (left)												2.3					
AR 6 km ds HCE (right)												1.7					
AR 6 km ds HCE (comp)									7	8.5	48		1.3	3	3.2	17	3.5
AR 11 km ds HCE									L1.			1.5					
												1.8					
AR 21 km ds HCE	8			14.1	86			0.008	56	34	49	2.5	1.5	3.2	3.5	13	2.4
												1.5					
AR 36 km ds HCE									2	2	45	1.4	1.1	2.1	2.5	10	2.9
												1.2					
Oldman Creek	5			L.5	7				1	1.6	4	1				4	2
AR 60 km ds HCE									L1.			1.3	1.1	1.7	2.3		
Spring 1	11			L.5	10							1.1					
AR above Berland	7	0.7	158	11.3	86	0.14	4.7	0.006	1	1.3	35	1.4	1.1	1.8	2.3	9	2.6
												1.1					
												1.6					
Berland River	8			L.5	31				L1.	0.9	6	0.9				4	1.7
Spring 2	5			L.5	3				L1.			0.1					
Marsh Head Creek	26			0.7	12				2	1.8	14	0.8				15	4.7
Pine Creek	14			1	41				2	2.5	6	0.3				16	2.8
Spring 3	4			L.5	L3.0				1			0.2					
Two Creek	66			2	18				2	2.7	17	1.2				15	6.4
AR 1.5 km ds Two Cr.									L1.			1.3					
Windfall Creek	13			L.5	8				2	7.4	14	1.3				12	4.2
Ar above Whitecourt	8	0.7	187	8.9	71	0.13	5.5	0.003	2	1.5	30	1.3	0.8	1.6	2	6	2.4
												1.5					
												1.2					
McLeod River	31	1.5	361	1.5	21	0.12	10.2		1	1.3	9	1.6				9	3.8
												1.6					
Millar Western Effluent	850	14.9	1510	28.2	771	0.62	130	0.011	1880	960	400	630	278	1170	1383	3050	529
AR 3 km ds McLeod							6.7		51	40	28	6.6				52	3.9
												6.5					
Whitecourt STP (grab)	109	8.6	430	85	48	0.82	15.2	0.006	4	2.8	35	6.4				35	10
AR 10 km ds McLeod							6.7		5	4	28	3.3	1.4	4.1	4.9	16	3.3
												2.5					

Appendix 3. Continued...

STATION	Na mg/L 11103L	K mg/L 19103L	HCO3 mg/L 06202L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SULFIDE mg/L 16200L	SS mg/L 10401L	TURB. NTU 02074L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD5D mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR at Blue Ridge Br.	14	0.8	212	7.9	67	0.14	6.6		1	1.6	28	1.4				12	
												1.8					
AR ds Five Mile Is.									L1.			1.2					2.9
												1.3					
AR at Ft. Assin.	16	0.9	215	8	68	0.13	6.7	0.004	2	2.5	29	0.9				9	3.6
												1					
Freeman River	15			3	10				2	9.1	9	0.5				10	4.5
AR above Pembina R.	16	0.9	223	7.9	70	0.14	6.9		1	2.3	29	0.8					3.9
												0.6					
Pembina R.	37			1.9	18				2	5.4	35	0.5				33	15.1
												0.4					
AR above Smith, @ Hwy 2	16	1	234	7.9	69	0.14	7	L.001	1	1.8	28	0.9	0.5	1.2	1.5	12	3.5
												1.1					
												0.7					
L.S.R.- lake outflow	7			1	11			0.004	1	1	19	1				26	11.6
Slave Lake STP	72			58.8	37			0.005	16	16.3	64	6.4				104	28.4
L.S.R. - Mitsue Bridge												1.1					
L.S.R.-Driftwood R.												0.8					
L.S.R. -AR confluence	7	2.8	121	1.1	13	0.11	0.9	L.001	7	3.6	20	0.9	0.7	1.1	1.7	28	11.3
AR north of Howie L.												1.2					
												1.9					
												1.9					
AR at Athabasca	15	1.7	207	5.4	50	0.12	5.2	0.002	1	2.6	20	1.4	0.5	1.6	1.8	22	6.3
												0.6					
												0.8					
									9			13.4					
T. of Athabasca STP	97			74.1	102				2	2.2	22					18	6.3
AR above La Biche R.								0.002				0.8					
									12	21	36	0.9				50	18
La Biche R.	22			4.2	25				6	12.6	32	0.8				27	10.9
Calling R.	14			1.1	32				2			0.8					
AR near McMillan L.												0.6					
									2			0.5					
AR above Pelican R.												0.9					
									10	10.8	138	3.1				110	41
Pelican R.	6			1	10				1	2.4	25	0.8				20	7
AR above House R.	16	1.6	197	6.4	50	0.13	5.1					0.8					
												0.8					
									9	13.7	54	0.9				41	15.7
House R.	30			1.9	61				1								
AR above Buffalo Cr.									1			0.7					
AR above Boiler Rapids																	

Appendix 3. Continued...

STATION	Na mg/L 11103L	K mg/L 19103L	HCO3 mg/L 06202L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SULFIDE mg/L 16200L	SS mg/L 10401L	TURB. NTU 02074L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD5D mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR above Horse R.	17	1.6	206	6.9	53	0.13	5.4	0.001	1	2.4	25	0.6	0.6	0.7	1	17	6.8
												0.6					
												0.5					
Horse River	44			11.5	32				2			1.2					
Clearwater River	42	1	88	53	10	0.1	12.3		7	5	35	1.2	1.2	1.3	1.9	16	6.1
												0.6					
Ft. McMurray STP	121			84	105			0.008	15	7.3	41	22.4				84	23.8
												15.4					
AR above Suncor									2			1.6					
												1.6					
Suncor Process Effl. (grab	90			105	97			0.003	14	17.2	22	4.3				33	7.7
Steepbank River	42			6.5	11				3	6.8	42	1.3				37	13.1
Muskeg River	15			4.5	6				2	11.6	71	1.7				56	23
Mackay River	54			16.2	50				2	11	145	1.5				78	27.6
Ells River	18			2.9	27				4	9	58	0.9				41	15
AR near Bitumount	35			33	37			0.003	3	3.5	28	1.4				20	6.9
												1					
AR above Firebag R.		2	3.2								28	1.2				21	6.6
												1.4					
Firebag River	4			3	6				3	3.4	35	1.7				21	6
												1.8					
AR at Old Fort	37	1.4	168	44.9	36	0.13	9.4	0.003	3	4.3	29	0.6	0.5	0.7	0.8	17	7.5
												0.2					
												0.8					
Richardson River	2			1	5				8	3.9	32	1.2				6	3.7
AR - Big Point Chan. Mouth		2	4.1								32	0.6				12	6.6
AR - Goose Is. Chan. Mouth		2	4								29	0.3				17	6.8

Appendix 3. Continued...

STATION	PC mg/L 06905L	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOTAL NH3-N mg/L 07505L	TKN mg/L 07015L	TPN mg/L 07906L	TDP mg/L 15105L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	STD.PL. COUNT #/mL 36905L	CHL-a ug/L 06715L
AR above Hinton	0.29	0.2	L.001	0.16	0.002	0.101	0.02	0.12	L.02		0.004		0.0049	L1.	58	100	
	0.39	0.1	L.001	0.18	0.001	0.11	0.02	0.08	L.02					L1.	12	150	0.2
	0.31	0.1	L.001	0.15	0.001	0.11	0.02	0.12	L.02					L1.	34	101	
						0.1											
Hinton comb. effl.	5.7	0.5	0.211	48.14	L.003	0.05	0.05	2.85	2.47			2.3		300	700	577000	
AR 1 km ds HCE						0.098	0.02	0.18									
AR 6 km ds HCE (left)						0.099	0.02	0.18									
AR 6 km ds HCE (right)						0.107	0.03	0.2									
AR 6 km ds HCE (comp)	1.35		0.007	1.54					0.06		0.0108		0.0267	8	51	137000	
AR 11 km ds HCE			0.007			0.101	0.02	0.22									
						0.101	0.02										
AR 21 km ds HCE	0.92	0.3	0.005	1.45		0.115	0.02	0.18	0.06		0.0094		0.0313	10	60	181000	1.9
						0.108	0.02										
AR 36 km ds HCE	0.65		0.005	1.34		0.11	0.03	0.24	0.05		0.0081		0.0187	11	39	45000	
						0.104	0.03										
Oldman Creek	0.09		L.001	0.24		0.125	L.010	0.16	L.02		0.0052		0.01				
AR 60 km ds HCE			0.006			0.114	0.03	0.2									
Spring 1			L.001			0.149	L.010	0.16			0.0045		0.0047				
AR above Berland	0.26	0.1	0.006	1.12	0.003	0.12	0.04	0.24	0.03		0.0059		0.0147	5	27	100	0.3
						0.119	0.04										
						0.118	0.04										
Berland River	0.15		L.001	0.3		0.05	0.01	0.12	L.02		0.0039		0.0057	L1.	2	105	
Spring 2			0.001			0.067	0.02	0.18			0.0071		0.0101				
Marsh Head Creek	0.14		0.003	0.62		0.082	0.02	0.24	L.02		0.0068		0.0113				
Pine Creek	0.27		0.001	0.28		0.109	0.02	0.16	L.02		0.0048		0.0098				
Spring 3			0.002			0.044	0.02	0.18			0.0067		0.024				
Two Creek	0.25		0.003	0.59		0.082	0.03	0.32	0.02		0.0092		0.0133				
AR 1.5 km ds Two Cr.			0.006			0.109	0.03	0.2									
Windfall Creek	0.34		0.002	0.48		0.076	0.04	0.26	0.02		0.0121		0.03				
Ar above Whitecourt		0.2	0.004	0.91	0.003	0.12	0.04	0.24	0.03		0.0052		0.0124			16100	0.2
						0.109	0.03	0.22									
						0.111	0.03	0.18									
McLeod River	0.15		0.002	0.46	0.003	0.13	0.1	0.42			0.0086		0.0124			10500	
						0.131	0.1		0.16								
M. W. Effluent	23.45	2.5	4.21	70.45	0.097	0.1	0.09	26	2.14			8.2		700	1000	450000	
AR 3 km ds McLeod	15.2		0.013	0.91		0.112	0.01	1.14	1.44		0.0118		0.1643			18500	
						0.109	0.03										
Whitecourt STP (grab)	1.12	0.4	0.01	1.5	0.345	1.64	7.8	8.6	0.18	4.32		4.5		570	2000	2300	
AR 10 km ds McLeod	2.39		0.012	0.95		0.108	0.03	0.28	0.19		0.014		0.0359			17700	
						0.109	0.02										
AR at Blue Ridge Br.			0.01	0.95	0.005	0.08	0.01	0.24			0.0076		0.0205			10100	
						0.109	0.01										

Appendix 3. Continued...

STATION	PC mg/L 06905L	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOTAL NH3-N mg/L 07505L	TKN mg/L 07015L	TPN mg/L 07906L	TDP mg/L 15105L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	STD.PL. COUNT #/mL 36905L	CHL-a ug/L 06715L
AR ds Five Mile Is.	0.98		0.008			0.11	0.01	0.2	L.02								
						0.102	0.01										
AR at Ft. Assiniboine	0.23	0.2	0.01	0.53	0.004	0.09	L.010	0.2	L.02		0.0114		0.0161	3	16	24000	0.1
						0.095	L.010										
Freeman River	0.29		0.004	0.35		L.003	0.12	0.34	L.02		0.0068		0.0102				
AR above Pembina R.	0.12		0.007	0.49	0.003	0.12	0.01	0.24	L.02		0.0102		0.0154	5	8	12000	
						0.124	0.01										
Pembina R.	0.15		0.007	0.6		0.161	0.15	0.8	L.02		0.0238		0.0285	1	2	L1.	
						0.163	0.15										
AR above Smith, @ Hwy 2	0.28	0.2	0.005	0.62	0.002	0.12	0.02	0.26	0.02		0.0052		0.0139	3	9	1100	0.1
						0.127	0.02										
						0.126	0.02										
L.S.R. -lake outflow	0.06	0.1	0.005	0.42		0.043	0.05	0.44	L.02		0.0102		0.0136			L1.	1
Slave Lake STP (grab)	4.25	0.7	0.022	1.59		0.09	20	26.8	0.79	2.85		4.4		840	2100		
L.S.R. -Mitsue Br.			0.005			0.05	0.07	0.44			0.0138		0.018			L1.	
L.S.R. -Driftwood R.			0.005			0.051	0.07	0.42									
L.S.R. -AR confluence	0.42	0.2	0.005	0.43	0.003	0.06	0.07	0.44	0.03		0.0105		0.0213	L1.	2	700	1.7
AR north of Howie L.						0.11	0.05	0.24									
						0.112	0.04										
						0.112	0.04										
AR at Athabasca	0.35	0.2	0.005	0.49	0.003	0.12	0.09	0.3	L.02		0.0115		0.0158				0.3
						0.118	0.06	0.28									
						0.118	0.07	0.28									
T. of Athabasca STP			0.019							5.75		6.1					
						2.3	20	24.6									
AR above La Biche R.	0.3	L.1	0.004	0.77		0.101	0.03	0.34	0.02		0.0084		0.0153	L1.	18	1000	
						0.103	0.03										
La Biche R.	0.9		0.008	0.94		0.216	0.55	1.06	0.09		0.034		0.1015	L1.	2	800	
Calling R.	0.34		0.004	0.33		0.284	0.13	0.6	0.04		0.0111		0.0431	L1.	L1.	800	
AR near McMillan L.			0.004			0.115	0.04	0.3			0.009		0.0166	L1.	10	200	
						0.117	0.04										
AR above Pelican R.			0.004			0.12	0.04	0.3									
						0.121	0.04										
Pelican R.	1.99		0.022	2.66		0.006	0.86	2.08	0.27		0.0195		0.0772	2	4	300	
AR above House R.	0.32	0.2	0.005	0.54	0.003	0.12	0.04	5.6	0.03		0.011		0.0179			880	
						0.123	0.03										
						0.123	0.03										
House R.	0.61		0.008	1.13		0.57	0.19	0.52	0.04		0.0353		0.1041				
AR above Buffalo Cr.			0.005								0.008		0.017				
AR above Boiler Rapids			0.004			0.132	L.010	0.36			0.0083		0.0165				
						0.133	L.010										

Appendix 3. Continued...

STATION	PC mg/L 06905L	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOTAL NH3-N mg/L 07505L	TKN mg/L 07015L	TPN mg/L 07906L	TDP mg/L 15105L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	STD.PL. COUNT #/mL 36905L	CHL-a ug/L 06715L
AR above Horse R.	0.03	0.2	0.005	0.53	0.002	0.13	0.02	0.36	L.02	0.006	0.0145	0.012	0.0161			900	0.3
						0.14	0.02	0.36									
						0.14	0.02	0.34									
Horse River			0.006			0.4	0.04	0.54									
Clearwater River	0.48		0.004	0.53	0.002	0.15	0.07	0.46	0.04		0.0266		0.0502				
						0.156	0.07										
Ft. McMurray STP(gr.)	8.06	1.6	0.017	1.49		0.97	18.8	24.8	1.84	1.9		2.5					
						1	18.6										
AR above Suncor			0.005			0.156	0.07	0.6			0.0162		0.0297	L1.	93	1000	
						0.155	0.07										
Suncor Process Effl. (grab	3.93	3.3	0.008	0.68		0.17	0.12	0.74	0.12	0.108		0.174					
Steepbank River	0.99		0.005	0.76		0.29	0.04	0.6	0.04				0.0762				
Muskeg River	0.79		0.008	1.37		0.169	0.29	0.88	0.05		0.0198		0.0411				
Mackay River	0.4		0.012	2.03		0.405	0.06	0.88	0.03		0.0912		0.1286				
Ells River	0.31		0.007	0.9		0.375	0.02	0.56	0.03		0.0299		0.0529				
AR near Bitumount	0.26	0.2	0.004	0.53		0.168	0.07	0.33	0.02		0.0199		0.0311				
						0.17	0.07										
AR above Firebag R.	0.26		0.004	0.52		0.168	0.07	0.32	0.03		0.0169		0.0283	L1.	32	3000	
						0.168	0.07										
Firebag River	0.3		0.003	0.56		0.165	0.05	0.32	0.02		0.0359		0.0521				
						0.14	0.05										
AR at Old Fort	0.33	0.2	0.004	0.58	0.003	0.17	0.07	0.48	0.04		0.0201		0.0335	L1.	70	22700	0.3
						0.155	0.07	0.54									
						0.16	0.07	0.46									
Richardson River	0.82		0.002	0.5		0.09	0.04	0.34	0.06		0.0364		0.0642				
AR - Big Point Chan.	0.25		0.004	0.54		0.159	0.06	0.46	0.02		0.0172		0.0301				
AR - Goose Is. Chan.	0.37		0.004	0.5		0.154	0.06	0.42	0.03		0.0176		0.031				

Appendix 3. Continued...

STATION	TOTAL Al mg/L 13030L	TOTAL As mg/L 33011L	TOTAL Ba mg/L 56009L	DISS. Be mg/L 04103L	TOTAL Cd mg/L 48009L	TOTAL Co mg/L 27009L	TOTAL Cr mg/L 24009L	TOTAL Cu mg/L 29009L	TOTAL Fe mg/L 26009L	TOTAL Hg mg/L 80015L	TOTAL Mn mg/L 25003L	TOTAL Mo mg/L 42009L	TOTAL Ni mg/L 28009L	EXTR. Pb mg/L 82302L	TOTAL Se mg/L 34011L	TOTAL V mg/L 23009L	TOTAL Zn mg/L 30009L
AR above Hinton	0.018	0.0004	0.06	L.001	0.001	L.001	0.002	0.001	0.064	L.0001	0.004	0.002	0.003	0.002	0.0002	0.002	L.001
	0.012	0.0004	0.064	L.001	0.002	L.001	0.002	L.001	0.087	L.0001	0.004	0.001	0.003	L.002	L.0001	0.003	L.001
	0.03	0.0003	0.063	L.001	0.002	L.001	0.002	0.001	0.084	L.0001	0.005	0.001	0.003	0.004	0.0001	0.002	L.001
Hinton comb. effl.	0.041	0.0006	0.135	L.001	0.003	0.002	0.009	0.013	0.518	0.0008	0.789	0.003	0.007	0.008	L.0001	0.004	0.106
AR 6 km ds HCE (comp)	0.012		0.067	L.001	L.001	L.001	0.002	0.001	0.089		0.031	0.002	0.003	0.002		0.003	0.002
AR 21 km ds HCE	0.006	0.0003	0.066	L.001	0.002	L.001	0.002	L.001	0.111	0.0004	0.029	0.002	0.003	L.002	0.0001	0.003	0.001
AR above Berland	0.006	0.0003	0.068	L.001	0.001	L.001	0.004	L.001	0.064	0.0001	0.008	0.002	0.003	L.002	L.0001	0.002	0.002
Ar above Whitecourt	0.039	L.0001	0.078	L.001	0.002	L.001	0.003	0.001	0.093	L.0001	0.005						
McLeod River	0.039		0.14	L.001	0.002	0.001	0.004	0.002	0.074	L.0001	0.007						
N. W. Effluent	0.245	0.002	0.229	L.001	0.011	0.004	0.012	0.026	1.313	L.0001	0.919	0.007	0.017	L.002	L.0001	0.01	0.31
Whitecourt STP (grab)	0.053		0.159	L.001	0.002	0.001	0.004	0.006	0.057	L.0001	0.141	0.002	0.007	0.011		0.003	0.113
AR at Blue Ridge Br.	0.03		0.083	L.001	0.002	0.001	0.004	0.001	0.081	L.0001	0.01						
AR at Ft. Assin.	0.026	0.0003	0.09	L.001	0.001	L.001	0.003	0.001	0.12	L.0001	0.01	0.002	0.004	L.002	L.0001	0.002	0.004
AR above Pembina R.	0.021		0.099	L.001	0.001	L.001	0.003	0.002	0.136	L.0001	0.007	0.002	0.004	0.005		0.003	0.009
AR ab. Smith, @ Hwy 2	L.002	0.0003	0.101	L.001	0.001	L.001	0.003	0.002	0.121	L.0001	0.005	0.001	0.003	0.007	L.0001	0.003	0.003
L.S.R. -AR confluence	L.002		0.065	L.001	L.001	L.001	0.001	0.003	0.259	L.0001	0.035	0.001	0.002	L.002		L.002	L.001
AR at Athabasca	0.013	0.0005	0.095	L.001	0.001	L.001	0.003	0.003	0.139	L.0001	0.005	0.001	0.003	L.002	L.0001	0.003	0.003
AR above House R.	0.023	0.0007	0.087	L.001	0.001	L.001	0.003	0.001	0.149	L.0001	0.008						
House R.	0.052	0.0011	0.055	L.001	0.001	0.002	0.004	0.001	1.659	L.0001	0.308						
AR above Horse R.	0.023	0.0007	0.091	L.001	0.001	0.001	0.003	0.001	0.159	L.0001	0.005						
Clearwater River	0.033		0.021	L.001	L.001	L.001	0.002	0.001	0.919	L.0001	0.052	L.001	0.002	L.002		0.003	L.001
AR at Old Fort	0.021	0.0004	0.061	L.001	L.001	L.001	0.004	0.001	0.556	L.0001	0.043	0.002	0.004	L.002	L.0001	0.003	0.004

Appendix 4. Survey 89-2 water quality data.

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR at Windfall Bridge	00AL07AE1350	177.1	26 1 89	43			9.61	7.8	7.85	422	448	251	148	213	59	16
AR ab. Whitecourt	00AL07AE1495	209.8	26 1 89		0	10.5	9.43									
							9.63									
McLeod River	00AL07AG2060	211	25 1 89	4.75												
					0.4	4.7	4.93	7.6	7.79	511	551	306	281	251	71	18
							4.58									
							5.32									
Millar Western Effl. (grab)	20AL07AH1000	211.5	26 1 89		17	8.1		8.2								
					17.5	8		8.1		3440						
					18	7.7		8.1		3430						
					18	7.8		8.2		3440						
					18	7.5		8.1		3430						
					18	7.5		8.1		3440						
					18	7.7		8.1		3440						
					18	7.7		8.1		3440						
M. W. Effl. (comp.)	20AL07AH1001	211.5	26 1 89	0.138	17.8	7.75		8.2	8.17	3420	3480	2470	1152	322	73	34
AR 3KM ds McLeod	00AL07AH0660	214	26 1 89		0	10.5	9.03	7.7		442						
							9.01									
							9.14									
Whitecourt STP (grab)	21AL07AH0200	214.9	26 1 89	0.037			4.68		7.44		896	491	331	274	80	18
							4.72									
AR 10 KM ds McLeod	00AL07AH1044	221.1	26 1 89		0	10.4	8.94	7.7		442						
							8.77									
							8.92									
AR at Blue Ridge Br.	00AL07AH1085	236.2	27 1 89		0.4	9.3	8.46	7.7	8.02	438	469	272	167	227	63	17
							8.34									
							8.31									
AR ds Five Mile Is.	00AL07AH1150	274.4	27 1 89		0.1	8.7	7.8	7.6		440						
							7.95									
							7.7									
AR ab. Freeman R.	100AL07AH1310	305.8	27 1 89		0	8	8.06	7.6	8.07	449	474	274	169	227	63	17
							7.94									
							7.81									
Freeman R.	00AL07AH2000	306	27 1 89	0.558	2.2	0	0	7.2		517						
							0									
							0									
AR ab. Pembina R.	00AL07BD0500	393.4	6 2 89		0	6.8	7.76	7.4		458						
							7.75									
							7.77									

Appendix 4. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
Pembina R.	00AL07BC0990	393.8	6 2 89		-0.3	0	1.4	7.4	7.62	603	629	362	331	284	76	23
							1.5									
							1.58									
AR ab. Smith (at Hwy. 2)	00AL07BD1000	437.5	6 2 89		-0.4	6.3	7.46	7.6	7.73	418	495	286	192	241	65	19
							7.68									
							6.95									
L. Slave R. (at lake outflow)	00AL07BK2100	-	6 2 89	23.9	0	13.5	13.14	8		201						
							13.43									
Slave L. STP	21AL07BK5000	-	6 2 89				7.43									
							7.23									
L. Slave R. (at AR confluence)	00AL07BK2150	449.4	6 2 89		-0.1	12.2	12.12	7.8	7.9	188	224	120	100	100	28	7.4
							12.26									
AR north of Howie L.	00AL07BE2200	511.1	6 2 89		-0.2	7.7	7.85	7.6		354						
							8.06									
							8.04									
AR at Athabasca	00AL07BE2320	556.4	6 2 89	69.8	-0.3	7.2	7.35	7.6	7.73	412	434	249	167	210	56	17

Appendix 4. Continued...

STATION	Na mg/L 11103L	K mg/L 19103L	HCO3 mg/L 06202L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SULFIDE mg/L 14105L	S mg/L 16200L	SS mg/L 10401L	TURB. NTU 02074L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD50 mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR ab. Whitecourt	8	0.7	180	10	68	0.12	5.3	0.003	1	1.6	33	1	0.2	1.3	1.4	10	2.6
												0.7					
												0.7					
McLeod River	27	1.3	343	1.6	18	0.11	9.9	0.002	1	1.4	9	L.1	0.3	0.5	0.7	9	3.4
												0.4					
												0.6					
M. W. Effl. (grab)	810	12.8	1404	27.7	821	0.7	132	0.01	1640	800	320	501	107	707	795	2844	340
AR 3KM ds McLeod									7	4.4	32	2.1				21	3.4
												2					
Whitecourt STP (grab)	80	9.3	403	47.1	46	0.88	15.8	0.004	4	1.9	33	5.3				32	9
AR 10 KM ds McLeod							6.4		6	3.1	32	1.9	0.8	2.6	3	17	3.3
												2.1					
AR at Blue Ridge Br.	15	0.8	204	9.2	66	0.12	6.5		6	4.2	29	2				15	3.4
												1.9					
									1			1.3					
AR ds Five Mile Is.																	
AR ab. Freeman R.	15	0.8	206	9.2	67	0.12	6.5	0.003	2	1.8	28	1.6	1.2	1.7	1.8	14	3.5
												1.7					
									9	33	7	1.9				12	4.7
Freeman R.									1	1.9	34	0.6				9	3.2
AR ab. Pembina R.							6.6					0.3					
												0.4				27	11.7
Pembina R.	38	2.5	403	1.8	21	0.13	10.1		2	4.1	25	0.2					
AR ab. Smith	17	1	234	8	60	0.13	4		2	2.5	29	0.7	0.1	1.1	1.2	11	4.3
(at Hwy. 2)												0.3					
												0.1					
L. Slave R.(lake outflow)	7			1	11				1	0.9	18	L.1				30	10.9
Slave L. STP	79			67.8	40			0.008	20	22	59	7.3				125	29
L. Slave R.	7	2.9	122	1	13	0.11	1	L.001	6	4.5	21	0.3	0.6	0.5	0.9	29	11.2
(at AR confluence)												0.9					
												0.8					
AR north of Howie L.												0.2					
AR at Athebasca	14	1.4	204	6.5	53	0.12	5.5	0.002	2	3.3	26	L.1	0.1	0.8	0.9	15	5.5

Appendix 4. Continued...

STATION	PC mg/L 06905L	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOTAL NH3-N mg/L 07505L	TKN mg/L 07015L	TPN mg/L 07906L	TDP mg/L 15105L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	STD.PL. COUNT #/mL 36905L	CHL-a ug/L 06715L
AR ab. Whitecourt	0.32	L.1	0.004	0.77	0.003	0.1	0.02	0.14	0.02		0.0035		0.0083	L1.	6	400	
						0.098	0.02	0.12									
						0.096	0.02	0.14									
McLeod River	0.23	0.1	0.001	0.18	0.003	0.16	0.12	0.28	L.02		0.0026		0.0063	L1.	L1.	400	
						0.153	0.12										
						0.151	0.12										
Millar Western Effluent (composite)	627.4	4.1	2.95	53.72	0.092	0.1	1.08	52	35.68			14		L1.	700	200000	
						0.028	0.15										
AR 3KM ds McLeod	2.08		0.011	1.19		0.104	0.03	0.28	0.13		0.0256		0.0487	8	14	2600	
						0.103	0.03										
Whitecourt STP (grab)	1.66	0.9	0.01	0.88	0.76	2.65	6.5	7	0.25	4.1		4.3		274	310	7500	
AR 10 KM ds McLeod	2		0.01	0.75		0.1	0.03	0.34	0.12		0.0285		0.0489	14	164	1700	
						0.102	0.04										
AR at Blue Ridge Br.	1.73	.	0.01	0.95	0.003	0.1	0.02	0.32	0.12		0.0269		0.0479	5	52	3000	
						0.103	0.02										
AR ds Five Mile Is.			0.007			0.104	0.01	0.22									
AR ab. Freeman R.	0.33	0.1	0.007	0.87	0.002	0.1	L.010	0.2	0.03		0.0173		0.0237	L1.	20	1800	
						0.101	L.010										
Freeman R.	0.99		0.003	0.4		L.003	0.12	0.32	0.05		0.0089		0.0376				
AR ab. Pembina R.	0.35		0.005	0.83		0.11	0.01	4.2	L.02		0.0198		0.0245	L1.	2	200	
						0.109	0.02										
Pembina R.	0.22		0.005	0.68	0.004	0.16	0.14	0.6	0.02		0.0125		0.0257	L1.	3	200	
						0.158	0.14										
AR ab. Smith, @Hwy 2	0.19	0.2	0.005	0.78	0.003	0.12	0.03	0.28	L.02	0.013	0.0182	0.018	0.0232	L1.	6	200	0.1
						0.122	0.03										
						0.12	0.04										
L. Slave R.(lake outflow)	0.1	0.2	0.005	0.33		0.051	0.03	0.52	L.02		0.0092		0.0126	L1.	L1.	100	
Slave L. STP	4.83	0.6	0.024	2.15	0.013	0.068	21	28.6	0.92	3.45		4.75		140	1370	2000	
L. Slave R. (at AR confluence)	0.47	0.2	0.005	0.36	0.005	0.08	0.05	0.72	0.05		0.0124		0.0235	L1.	2	200	
						0.074	0.06										
AR north of Howie L.						0.107	0.02	0.38									
AR at Athabasca	0.29	0.2	0.005	0.62	0.004	0.11	0.02	0.36	L.02		0.0121		0.018	L1.	L1.	900	
						0.109	0.02	0.36									
						0.107	0.02	0.34									

Appendix 4. Continued...

STATION	TOTAL Al mg/L 13030L	TOTAL As mg/L 33011L	TOTAL Ba mg/L 56009L	DISS. Be mg/L 04103L	TOTAL Cd mg/L 48009L	TOTAL Co mg/L 27009L	TOTAL Cr mg/L 24009L	TOTAL Cu mg/L 29009L	TOTAL Fe mg/L 26009L	TOTAL Hg mg/L 80015L	TOTAL Mn mg/L 25003L	TOTAL Mo mg/L 42009L	TOTAL Ni mg/L 28009L	EXTR. Pb mg/L 82302L	TOTAL Se mg/L 34011L	TOTAL V mg/L 23009L	TOTAL Zn mg/L 30009L
AR ab. Whitecourt	0.033	0.0003	0.076	L.001	0.001	L.001	0.003	L.001	0.098	L.0001	0.007	0.001	0.004	0.003	L.0001	0.003	0.003
McLeod River	0.019	0.0004	0.146	L.001	0.001	L.001	0.025	0.001	0.07	L.0001	0.007	L.001	0.004	0.003	L.0001	0.002	0.002
Millar Western Effluent			0.154	L.001	0.01	0.005	0.017	0.02	1.259		1.06	0.006	0.018	0.005		0.013	0.282
Whitecourt STP (grab)	0.029		0.152	L.001	0.002	0.001	0.003	0.007	0.06		0.155	0.003	0.007	L.002		0.003	0.06
AR at Blue Ridge Br.	0.037		0.083	L.001	0.001	L.001	0.002	0.004	0.115		0.014	0.002	0.005	L.002		0.003	0.002
AR ab. Freeman R.	0.029		0.084	L.001	0.002	0.001	0.003	0.004	0.112		0.009	0.002	0.005	L.002		0.003	0.002
Pembina R.	0.023	0.0008	0.165	L.001	0.002	0.002	0.005	0.002	0.315	0.0001	0.04	0.004	0.006	0.003	L.0001	0.004	L.001
AR ab. Smith, @Hwy 2	0.028	0.0004	0.098	L.001	0.001	0.001	0.004	0.001	0.171	L.0001	0.009	0.002	0.004	L.002	L.0001	0.003	0.002
L Slave. R. at lk out.	0.017		0.062	L.001	L.001	L.001	0.003	0.001	0.04		0.005	0.001	0.004	L.002		L.002	L.001
Slave L. STP	0.029		0.026	L.001	0.001	0.002	0.003	0.009	1.804		0.398	0.002	0.007			0.002	0.043
L. Slave R. nr. AR conf.	0.028	0.0011	0.065	L.001	L.001	L.001	0.002	0.001	0.286	0.0001	0.044	L.001	0.003	L.002	L.0001	L.002	L.001
AR at Athebasca	0.019	0.0006	0.088	L.001	0.001	L.001	0.003	0.001	0.169	L.0001	0.008	0.001	0.004	L.002	L.0001	0.002	0.002

Appendix 5. Survey 89-3 water quality data.

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR above Hinton	00AL07AD1085	0	13 2 89	28			11.16		8		415	244	123	216	55	19
							11.08		8.03		416	243	124	216	55	19
							11.17		8.03		416	243	124	216	55	19
Hinton Comb. Effl. (grab)	20AL07AD1000	1.9	13 2 89		21.2	7.1		7.7		1750						
					21.5	7.1		7.6		1780						
					21.2	7		7.6		1786						
					21.9	7		7.6		1780						
					22	7		7.7		1780						
					22	6.9		7.6		1780						
			14 2 89		22.5	7.2		7.7		1786						
					22	7.4		7.7		1788						
HCE (composite)	20AL07AD1001	1.9	13 2 89	1.02					7.75		1760	1010	142	389	123	20
AR 1 km ds HCE	00AL07AD1180	3	13 2 89				10.92									
							11									
AR 6 km ds HCE (left)	00AL07AD1200	7.5	13 2 89		0.7	11.2	11.4	8.1		435						
AR 6 km ds HCE (right)	00AL07AD1220	7.5	13 2 89		0.7	11	11.4	8.2		443						
							11.13									
AR 6 km ds HCE (comp)	00AL07AD1225	7.5	13 2 89													
AR 11 km ds HCE	00AL07AD1280	12.9	13 2 89		0	10.9	11.08	8.1		441						
							11.07									
AR 21 km ds HCE	00AL07AD1380	22.9	13 2 89		-0.2	10.5	10.73	8.1	8.02	450	463	269	125	221	57	19
							10.7									
AR 36 km ds HCE	00AL07AD1565	38.6	13 2 89		-0.1	10	10.32	8		451						
							10.41									
							10.11									
Oldman Creek	00AL07AD1700	55.7	14 2 89		0.4	12.8	12.61	8.3	8.14	364	388	210	210	202	58	14
				0.95			13.06									
AR 60 km ds HCE	00AL07AD1765	62.2	14 2 89		0.1	10.1	9.83	8		443						
							10.25									
Spring 1	00AL07AD2001	78.4	14 2 89		4	11.5	11.55	8.1	8.14	426	437	243	232	224	65	15
				0.03			11.55									
AR above Berland	00AL07AD2060	103.8	14 2 89		-0.4	9.8	9.96	8	7.89	444	455	266	133	230	59	20
							9.56									
							9.99									
Berland River	00AL07AC1000	104.2	14 2 89		-0.2	9.4	9.74	7.8	7.78	435	454	251	224	238	64	19
				5.52			9.47									
AR below Berland	00AL07AE0800	105	16 2 89	39												
Spring 2	00AL07AE0501	119	14 2 89	0.015	1.3	12.2	11.88	8.2	8.21	464	476	263	263	261	73	19
							12.13									

Appendix 5. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
Marsh Head Creek	00AL07AE0900	131.7	15 2 89		0.5	11.6	11.63	7.7	7.91	519	547	306	293	251	69	19
				0.173			11.76									
Pine Creek	00AL07AE1050	131.9	15 2 89		0	12.3	12.02	7.6	7.74	307	324	175	153	151	44	10
				0.31			12.16									
Spring 3	00AL07AE1141	149.7	15 2 89		0.1	11.7	11.38	7.8	7.95	372	389	211	208	208	62	13
				0.02			11.19									
Two Creek	00AL07AE1230	158.9	15 2 89		-0.2	10.4	10.34	7.8	7.83	601	629	357	331	217	62	15
				0.014			10.6									
AR 1.5 km ds Two Cr.	00AL07AE1260	160.5	15 2 89		-0.4	9.6	10.23	7.8	7.91	442	459	266	151	236	63	19
							9.42									
Windfall Creek	00AL07AE1290	166.9	15 2 89		-0.4	11.2	10.56	7.4	7.63	305	320	165	165	144	41	10
				0.503			10.99									
AR at Windfall Bridge	00AL07AE1350	177.1	17 2 89	45.5												
AR above Whitecourt	00AL07AE1495	209.8	15 2 89		0.5	9.4	9.52	7.7	7.88	419	456	260	151	224	60	18
							9.33									
							9.62									
McLeod River	00AL07AG2060	211	16 2 89	4.63	0.1	5.4	5.83	7.5	8.05	507	525	302	269	246	69	18
							6.06									
M. W. Effl. (grab)	20AL07AH1000	211.5	16 2 89		17.4	7.4		8.2		4610						
					17.5	7.5		8.1		4640						
					17.9	7.2		8		4640						
					17.9	7.2		8		4650						
					17.7	7.4		8		4650						
					17.6	7.3		8		4650						
					17.6	7.4		8		4660						
			17 2 89		17.1	7.7		8.1		4640						
M.W. Effl. (comp.)	20AL07AH1001	211.5	16 2 89	0.124						4630		3299	1644	363	68	47
AR 3 km ds McLeod	00AL07AH0660	214	16 2 89		-0.3	9.4	9.29	7.7	8.03	392	469	273	164	229	62	18
							9.34									
Whitecourt STP (grab)	21AL07AH0200	214.9	16 2 89	0.035	6	4.4		7.3	7.77	1030	1019	567	288	268	76	19
AR 10 km ds McLeod	00AL07AH1044	221.1	16 2 89		-0.1	8.7	8.88	7.9	7.92	457	472	277	168	234	64	18
							8.86									
AR at Blue Ridge Br.	00AL07AH1085	236.2	16 2 89		0	7.9	8.62	7.8	8.03	459	496	290	177	241	65	19
							8.51									
AR ds Five Mile Is.	00AL07AH1150	274.4	20 2 89		0.1	7.5	7.41	7.7		454						
							7.39									
							7.2									

Appendix 5. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR at Ft. Assin.	00AL07AH1310	305.8	20 2 89		0.2	7	7.01 6.92 6.87	7.7	7.74	461	481	278	172	233	62	19
Freeman R.-west mouth	00AL07AH1990	306	20 2 89						7.46		379	207	193	180	54	11
Freeman River	00AL07AH2000	306	20 2 89	0.59	0.2	9.9	9.41 9.49	7.4		358						
AR above Pembina R.	00AL07BD0500	393.4	20 2 89		-0.2	6.3	6.35 6.44 6.24	7.7	7.68	475	493	284	178	240	63	20
Pembina R.	00AL07BC0990	393.8	20 2 89		-0.2	0	1.48 1.45 1.44	7.5	7.55	582	606	342	319	279	77	21
AR above Smith, @ Hwy 2	00AL07BD1000	437.5	22 2 89	2.91	-0.2	5.5	5.89 5.62 6.21	7.7	7.86	481	501	284	189	226	59	19
L.S.R.-lake outflow	00AL07BK2100	-	21 2 89		0.8	13.5	13.02 13.01	8	7.97	200	217	114	96	90	26	6
Slave Lake STP (grab)	21AL07BK5000	-	21 2 89	22.7			0 0		7.6		819	396	234	141	40	10
L.S.R.-Hitsue Bridge	00AL07BK2110	-	21 2 89		0	13.3	12.71 12.82	8	7.89	198	216	115	95	90	26	6
L.S.R. u/s Driftwood	00AL07BK2130	-	21 2 89		0	13.2	12.71 12.65	7.9	7.93	203	220	118	98	96	27	7
L.S.R. at AR confl.	00AL07BK2150	449.4	23 2 89		0.1	12.3	12.11 12.01	.9	7.75	204	221	115	98	91	25	7
AR north of Howie L.	00AL07BE2200	511.1	23 2 89		0	7.6	7.84 7.83 7.69	7.7		398						
AR at Athabasca	00AL07BE2320	556.4	23 2 89	75.2	-0.3	7.8	8.09 7.87 8.06	7.7	7.66	410	429	243	164	196	52	16
T. Athabasca STP	21AL07C80100	557.4	9 3 89	0.012					7.64		1103	573	305	215	58	17
AR above La Biche R.	00AL07C82410	617.4	1 3 89		0.1	7.5	7.32 7.61 7.62	7.5	8.06	404	420	251	163	199	55	15
La Biche R.	00AL07CA1500	617.8	1 3 89		-0.3	3.4	3.38 2.95	6.8	7.55	576	603	350	272	275	74	22
Calling R.	00AL07C82500	633.3	1 3 89	0.426 0.022	0	11.1	11.18 12.08	7	7.89	535	557	324	254	275	79	19

Appendix 5. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR near McMillan L.	00AL07CB3300	677.9	1 3 89		0		7.71 7.55 7.84		7.88		428	246	165	203	55	16
AR above Pelican R.	00AL07CB3800	740.4	1 3 89		-0.1	6.9	7.13 7.04 7.02			370						
Pelican R.	00AL07CB3900	742.1	1 3 89	0.154	-0.2	13	13.12 12.92		7.68	215	248	132	115	110	29	9.2
AR above House R.	00AL07CB4150	799.9	7 3 89		0.4	6.8	7.46 7.19 7.24	7.7	7.79	405	434	250	169	185	51	14
House R.	00AL07CB4500	800.4	8 3 89 7 3 89	68.7	0.2	9.1	9.11 9.02	7.4	7.42	498	528	310	226	222	61	17
AR above Grande Rapids	00AL07CC2050	807.6	8 3 89 7 3 89	0.272	0.3	7.1	7.11 7.12 7.18	7.6		410						
AR above Buffalo Cr.	00AL07CC3050	844.9	7 3 89		0	11.8	11.4 11.42	7.7		415						
Buffalo Cr.	00AL07CC4000	844.9	7 3 89		-0.1	13.1	13.16 13.2	8.2	8.06	910	946	592	419	271	64	27
AR above Boiler Rapids	00AL07CC4050	887.5	8 3 89 7 3 89	0.014	-0.1	11.1	11.57 11.57 11.62	7.6	7.65	420	443	251	171	197	54	15
AR above Horse R.	00AL07CC0600	945.8	6 3 89 8 3 89	71.8	-0.2	12	12.06 11.75 11.78		8.05	426	447	249	173	192	52	15
Horse River	00AL07CC0750	947.3	6 3 89 8 3 89	0.39	-0.2	12.9	12.98 12.98	7.9	8.24	703	733	421	343	279	72	24
Clearwater River	00AL07CD1200	950.6	5 3 89 8 3 89	46.3	-0.4	12.5	12.52 12.58 12.49	7.4	7.58	339	355	178	68	58	15	5
Ft. McMurray STP	21AL07DA1000	950.5	8 3 89	0.088			14.12 14.26		7.66		957	581	172	216	55	19

Appendix 5. Continued...

STATION	ST. CODE	DISTANCE d/s km	DATE d m yr	FLOW cms 97160S	TEMP. C 02061F	DO mg/L 08102F	DO mg/L 08101L	pH 10301F	pH 10301L	SPEC. COND. uS/cm 02041F	SPEC. COND. uS/cm 02041L	TDS mg/L 00205L	ALKAL. mg/L 10101L	HARDN. mg/L 10605L	Ca mg/L 20103L	Mg mg/L 12102L
AR above Suncor	00AL07DA0985	978.2	8 3 89		-0.2	11.8	12.13 11.82	7.6		406						
							12.32									
Suncor Process Effl.	20AL07DA1000	981	8 3 89		9.5		3.91		7.95		880	489	159	216	60	16
							3.92									
Steepbank River	00AL07DA1200	983.1	7 3 89	0.274	0.3	12.9	13.18	8.1	8.2	576	610	342	318	245	62	22
							13.18									
Muskeg River	00AL07DA2650	998.9	7 3 89	0.501												
			9 3 89		0	5.9	6.08	7.3	7.64	464	496	267	256	237	67	17
							5.87									
Mackay River	00AL07DB1050	1002.8	7 3 89	0.625												
			9 3 89		0	12.2	11.85	7.8	7.98	664	697	400	291	243	61	22
							11.81									
Ells River	00AL07DA3350	1020.2	7 3 89	0.67												
			9 3 89		0	12.5	12.39	7.5	7.92	232	277	149	114	107	29	8.3
							12.34									
AR near Bitumount	00AL07DA4250	1029	9 3 89		-0.2	11.5	11.52	7.5	8.02	419	439	242	138	149	40	12
							11.61									
AR above Firebag R.	00AL07DA5050	1072	15 3 89		0.2	10.8	10.95	7.5		452						
							10.64									
Firebag River	00AL07DC0900	1075.7	15 3 89		0.2	5.2	4.84	7.2	7.74	251	268	135	131	122	33	9.7
					0.2	5.2	5.74	7.2	7.72	251	268	136	131	122	33	9.7
			17 3 89	6.73												
AR at Old Fort	00AL07DD0900	1156.8	15 3 89		0	10.7	9.95	7.2	7.7	472	483	258	141	145	40	11
					0	10.7	9.91	7.2	7.73	472	486	260	142	148	41	11
							9.85									
Richardson River	00AL07DD1140	1188.2	16 3 89		0.3	7	6.8	6.9	7.33	87	101	55	46	42	10.7	3.6
					0.3	7	6.78	6.9	7.26	87	103	50	46	39	10.5	3
			17 3 89	10.1												
AR - Big Point Chan.	00AL07DD1800	1238.7	16 3 89		-0.2	9.7	9.67	7.4	7.73	419	436	233	128	136	37	10.6
							9.81									
AR - Goose Is. Chan.	00AL07DD1700	1243.4	16 3 89		-0.1	9.7	9.67	7.5		429						
							10.28									

Appendix 5. Continued...

STATION	Na mg/L 11103L	K mg/L 19103L	HCO3 mg/L 06202L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SULFIDE mg/L 16200L	SS mg/L 10401L	TURB. NTU 02074L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD5D mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR above Hinton	2	0.5	150	1	92	0.14	4.3	0.006	16	4	1	1.5	0.4	1.6	1.8	L4.0	1.1
	2	0.5	151	1	91	0.14	4.3	L.001	18	4.9	1	0.9				L4.0	0.4
	2	0.5	151	1	91	0.14	4.3	L.001	14	5.3	1	0.6				L4.0	0.3
Hinton Comb. Effl.	229	5.7	173	355.5	191	0.2	7.4	0.104	38	27	2140	20.9	15.3	39.4	41.3	343	88
AR 1 km ds HCE									20	12	52	0.4				11	2.9
AR 6 km ds HCE (left)												0.4					
AR 6 km ds HCE (right)												0.3					
AR 6 km ds HCE (comp)									9	6.5	44	1.3	0.7	1.6	1.9	13	2.5
AR 11 km ds HCE									52			0.1					
												0.5					
AR 21 km ds HCE	9	0.7	152	12.5	95	0.14	4.5	0.005	15	10.4	48	0.4	0.3	1.7	1.9	11	2.7
												0.5					
AR 36 km ds HCE									13	7.1	49	0.7	0.5	1.7	2	13	3
												1.1					
Oldman Creek	6	0.6	256	L.5	4	0.08	10.3		2	2	4	0.7				L4.0	1
AR 60 km ds HCE									4			1.2	1.2	1.9	2		
Spring 1	13	0.9	283	0.6	8	0.08	8.1		L1.	0.1	3	1				4	1.9
AR above Berland	8	0.7	162	10.2	88	0.14	4.8	0.003	2	1.8	38	1.1	0.6	1.5	1.7	6	2.9
												1					
												1.1					
Berland River	8	0.8	273	0.7	24	0.11	7.7		L1.	0.9	1	1				L4.0	1.6
Spring 2	6	1	321	0.5	5	0.07	9.6		6	2.4	9	0.7				6	3.2
Marsh Head Creek	23	1.1	357	7	11	0.11	10.6		1	2.3	7	0.7				6	3.9
Pine Creek	10	0.8	187	1	17	0.09	9.8		3	4.6	7	0.5				6	2.7
Spring 3	5	0.9	254	0.5	5	0.09	8.9		3	4.5	7	0.6				7	3.9
Two Creek	60	1.5	403	2	17	0.17	10.9		3	3.4	13	0.7				9	5.2
AR 1.5 km ds Two Cr.	7	0.7	184	8.2	77	0.14	5.4		1	1.2	25	0.4				8	2.6
Windfall Creek	8	0.8	201	0.6	5	0.1	11.7		6	7.5	16	0.4				5	3.1
AR above Whitecourt	7	0.7	184	9	74	0.14	5.6	0.004	3	1.4	33	0.4	0.4	0.6	0.9	8	2.6
												0.6					
												0.4					
McLeod River	27	1.2	328	1.5	23	0.11	9.5		2	1.7	4	0.8				6	3.2
												0.8					
M. W. Effl.	1135	20.7	2004	34.4	1008	1.12	130	0.013	2200	1120	750	557	54.4	891		2900	577
AR 3 km ds McLeod	13	0.8	200	7.9	72	0.13	6.2		7	3.3	22	2.6				14	3.4
												2.3					
Whitecourt STP (grab)	115	8.6	351	101	42	0.9	14.9	0.004	14	1.4	28	8.1				27	10.4
AR 10 km ds McLeod	14	0.8	205	7.6	71	0.14	6.4		5	2.3	22	2.6	1	3.4	3.6	11	3.7
												1.9					
AR at Blue Ridge Br.	15	1	216	8.4	75	0.14	6.8		8	3.7	25	1.9				13	3.8
												2.3					

Appendix 5. Continued...

STATION	Na mg/L 11103L	K mg/L 19103L	HCO3 mg/L 06202L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SULFIDE mg/L 16200L	SS mg/L 10401L	TURB. NTU 02074L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD50 mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR ds Five Mile Is.									6	3.4	19	3.2				13	3.3
												3.1					
AR at Ft. Assin.	16	0.8	210	8	68	0.14	6.6	0.002	3	2.5	22	1.5	1.5	1.6	1.8	12	3.6
												1.6					
Freeman R.-west	14	1.1	235	1.9	9	0.12	14.1		9	9.2	19	1.2				18	7.6
AR above Pembina R.	16	0.9	217	8.9	68	0.13	6.9		2	2.3	22	1.7				10	3.3
Pembina R.	33	2.4	389	1.9	15	0.12	10.2		2	3.6	22	1.5				28	11.8
												1.3					
AR above Smith	18	1	230	8.3	65	0.14	7.1	0.004	1	2.4	17	1.7	0.8	1.8	2.1	13	5.6
												1.8					
												1.9					
L.S.R.-lake outflow	7	2.9	117	1.3	13	0.1	0.3	0.001	1	0.7	12	0.4				28	10.8
Slave Lake STP (grab)	79	12	286	70.9	43	1.06	13.7	0.009	20	15.5	61	18.7				114	33.1
L.S.R.-Hitsue Bridge	7	2.8	116	1.8	14	0.1	0.4		L1.	1.3	10	0.4				28	11.2
L.S.R.-Driftwood R.	7	2.9	119	1.5	13	0.1	0.6		2	2.3	12	0.1				34	11
L.S.R.-AR confluence	7	2.8	119	1.1	13	0.11	0.7	0.002	4	2.6	14	0.4	0.2	0.5	1.2	32	10.8
AR north of Howie L.												0.2					
												0.3					
AR at Athabasca	16	1.6	200	7	51	0.13	5.4	0.006	2	2.4	22	0.6	L.1	0.7	1.3	101	6.6
												0.5					
												0.4					
T. of Athabasca STP	107	12.2	372	91	104	0.97	10.5	0.003	8	4.9	51	15.3				82	28.7
AR above La Biche R.	18	2.6	199	10.6	51	0.12	5.1	0.002	L1.	2.2	29	0.5				16	7.1
												0.3					
La Biche R.	31	3.6	332	6	48	0.19	12.2	0.003	11	23	36	2.1				58	22.1
Calling R.	19	2.4	310	1.6	49	0.13	10.1		10	14.5	10	0.6				18	10.2
AR near McMillan L.	15	1.6	201	6.1	53	0.13	5.2	0.003	2	2.6	22	0.8				16	7.3
												0.2					
AR above Pelican R.	15			7	52				3	2.8	25	0.3				16	7.9
												0.6					
Pelican R.	7	1.9	140	1	15	0.13	4.6		7	7.9	151	1.6				167	48.2
AR above House R.	21	1.6	206	6	54	0.12	5.6	0.005	2	2.3	17	0.8				17	7.4
												0.6					
												0.4					
House R.	33	2.4	276	3	55	0.26	16.9		8	8.3	30	0.6				33	15.3
									1								
AR above Buffalo Cr.									5	8.1	84	0.7				78	33
Buffalo Cr.	126	2.9	511	2	115	0.35	10.8		1	2.1	17	1.1				16	8.3
AR above Boiler Rapids	17	1.6	208	6.5	53	0.12	5.7					0.4					

Appendix 5. Continued...

STATION	Na mg/L 11103L	K mg/L 19103L	HCO3 mg/L 06202L	Cl mg/L 17203L	SO4 mg/L 16306L	F mg/L 09107L	SiO2 mg/L 14105L	SULFIDE mg/L 16200L	SS mg/L 10401L	TURB. NTU 02074L	TRUE COLOUR RCU 02021L	BOD5 mg/L 08202L	BOD5D mg/L 08214L	BOD10 mg/L 08203L	BOD14 mg/L 08204L	COD mg/L 08304L	DOC mg/L 06107L
AR above Horse R.	18	1.7	211	7.8	50	0.13	5.8		2	2.4	17	0.6	0.5	0.9	1	28	7.3
												0.1					
												0.4					
Horse River	60	2.8	418	20.1	34	0.24	15.9		3	5.4	32	0.4				29	13.5
Clearwater River	45	1.1	83	60.2	10	0.1	13.1	0.001	6	5.6	22	0.3	L.1	0.8	0.9	12	6.1
												0.4					
Ft. McMurray STP	112	9.7	210	78.2	111	0.77	9.4	0.006	6	4.8	29	70.2				48	18
												72.1					
AR above Suncor									3	3.4	17	0.4				15	7.3
												0.6					
Suncor Process Effl. (grab	93	3.8	194	114	106	0.16	7.2	0.007	14	24	13	1.9				37	9.1
Steepbank River	46	2	388	7.8	10	0.26	13.1		4	5.3	95	0.8				27	12.6
Muskeg River	16	1.5	312	4.9	6	0.15	13.4		3	11.4		0.6				91	21.7
Mackay River	62	2.6	355	21.2	54	0.2	11.7		4	10.5	174	0.8				70	29
Ells River	15	1.5	139	3	22	0.14	6.1		4	7.9	51	0.6				38	15.5
AR near Bitumount	34	1.6	168	33	38	0.13	8.6	0.002	3	3.7	32	0.5				14	7.3
												0.5					
AR above Firebag R.									13	3.3	20	1.4				14	7.1
												1.2					
Firebag River	4	1	160	2.8	5	0.12	16.7		13	4.8	23	0.8					7.3
	4	1	160	2.6	6	0.12	16.7		3	3.4	22	0.8				10	5.9
AR at Old Fort	38	1.4	172	42.8	39	0.12	9.2	0.003	5	4	19	1.8	0.9	1.8	2	14	7.3
	38	1.4	173	43	39	0.12	9.4		2	4		0.6					
											19	0.7					
Richardson River	3	0.8	56	1.1	8	0.07	16.7		1	3.4	22	0.7				9	3.3
	2	0.7	56	0.9	5	0.06	16.9		7	3.3	24						3.4
AR - Big Point Chan.	35	1.3	156	37.9	34	0.12	10.3		12	3.4	22	0.7				14	6.1
AR - Goose Is. Chan.									2	3.9	24	0.6				14	6.8

Appendix 5. Continued...

STATION	PC mg/L 06905L	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOT. NH3-N mg/L 07505L	DISS. NH3-N mg/L 07562L	TKN-N mg/L 07015L	TPN mg/L 07906L	TDP mg/L 15105L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	STD. PL.CNT. #/mL 36905L	Chl-a mg/L 06715L
AR above Hinton	1.41	0.1	0.001	0.08	0.001	0.1	0.02		0.2	L.02		0.0027		0.0135	L1.	4	300	0.2
	1.66	0.2	L.001	0.05	0.001	0.1	0.02		0.2	0.02					L1.	6	700	
	0.76	0.3	L.001	0.05	0.001	0.1	0.02		0.2	L.02					L1.	14	100	
N.C.E. - comp.	17.54	0.4	0.024	38.58	0.058	L.01	0.82		3.8	1.94			0.61		L1.	140	850000	
AR 1 km ds NCE	3.03		0.01	1.24		0.111	0.05		0.32	0.08		0.0036		0.0309	L1.	100	20000	
AR 6 km ds NCE (left)						0.113	L.010											
AR 6 km ds NCE (right)						0.112	0.05											
AR 6 km ds NCE (comp)	1		0.007	1.03			0.26			0.06		0.0039		0.0205	L1.	140	21000	
AR 11 km ds NCE			0.011			0.117	0.03		0.36									
						0.116	0.03											
AR 21 km ds NCE	1.51	0.2	0.009	1.4	0.003	0.1	0.04		0.32	0.07		0.0049		0.0255	L1.	84	12000	0.6
						0.115	0.04											
AR 36 km ds NCE	1.47		0.01	1.24		0.126	0.05		0.32	0.07		0.0064		0.0262	L1.	130	10000	
						0.12	0.05											
Oldman Creek	0.09		L.001	0.11	0.001	0.14	L.010		0.22	L.02		0.003		0.0068				
AR 60 km ds NCE			0.008			0.114	0.04		0.32									
Spring 1	L.02		L.001	0.17	0.001	0.19	L.010		0.2	L.02		0.0026		0.0031				
AR above Berland	0.37	0.2	0.007	0.99	0.004	0.12	0.04		0.32	0.03		0.0084		0.0138	L1.	48	25000	0.4
						0.124	0.06											
						0.124	0.06											
Berland River	0.07		0.001	0.18	0.001	0.08	L.010		0.18	L.02		0.0021		0.003	L1.	24	L1.	
Spring 2	0.2		0.001	0.34	0.002	0.07	L.010		0.26	L.02		0.0038		0.0082				
Marsh Head Creek	0.15		0.001	0.37	0.002	0.12	0.02		0.28	L.02		0.0028		0.0078				
Pine Creek	0.25		0.001	0.18	0.001	0.09	0.02		0.2	0.02		0.0021		0.0084				
Spring 3	0.33		0.003	0.21	0.001	0.04	0.05		0.28	0.02		0.0045		0.0215				
Two Creek	0.21		0.004	0.34	0.002	0.13	0.02		0.3	L.02		0.0051		0.0112				
AR 1.5 km ds Two Cr.	0.07		0.005	0.67	0.003	0.12	0.04		0.24	L.02								
Windfall Creek	0.34		0.001	0.25	0.002	0.09	0.03		0.26	0.02		0.0056		0.0228				
Ar above Whitecourt	0.19	0.3	0.005	0.83	0.004	0.12	0.04		0.26	L.02		0.0039		0.0105	L1.	4	6500	0.1
						0.112	0.06		0.24									
						0.113	0.05		0.24									
McLeod River	0.16	0.2	0.002	0.26	0.002	0.2	0.12		0.38	L.02		0.003		0.0084	L1.	12	80	
						0.196	0.12											
Millar Western Effl.	78.1		3.56	68.76	0.024	0.02	0.08		56	4.21			34					
AR 3 km ds McLeod	2.16		0.012	0.74	0.004	0.12	0.03		0.44	0.13		0.0614		0.088	L1.	22	2900	
						0.116	0.03								L1.	2000	15600	
Whitecourt STP (grab)	1.67	1.1	0.011	1.14	0.55	7.3	1.55		3.52	0.29	4.15		4.22		L1.	32	26300	
AR 10 km ds McLeod	1.9		0.01	0.71	0.005	0.12	0.03		0.48	0.13		0.0654		0.0914	L1.	60	16500	
						0.124	0.03											
AR at Blue Ridge Br.	2.3		0.012	0.83	0.006	0.1	0.03		0.46	0.16		0.0644		0.0981	L1.			
						0.135	0.03											

Appendix 5. Continued...

STATION	PC mg/L 06905L	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOT. NH3-N mg/L 07505L	DISS. NH3-N mg/L 07562L	TKN-N mg/L 07015L	TPN mg/L 07906L	TDP mg/L 15105L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	STD. PL.CNT. #/mL 36905L	Chl-a mg/L 06715L
AR ds Five Mile Is.	1.29		0.009	0.96		0.128	0.03		0.3	0.03								
						0.129	0.03											
AR at Ft. Assin.	0.62	0.3	0.008	0.86	0.003	0.13	0.01		0.3	0.04		0.054		0.0667	L1.	40	4800	0.2
						0.131	0.02											
Freeman R.-west mouth	0.3		0.004	0.41	0.002	0.08	0.04		0.42	L.02								
Freeman River												0.0058		0.0208				
AR above Pembina R.	0.39		0.006	0.8	0.003	0.14	0.02		0.28	0.03		0.0433		0.0535	L1.	8	1400	
Pembina R.	0.28		0.006	0.32	0.003	0.12	0.18		0.72	0.02		0.0166		0.0271	L1.	40	270	
						0.119	0.18											
AR above Smith, @ Hwy 2	0.34	0.2	0.007	0.53	0.003	0.14	0.03		0.3	0.02		0.0444		0.0548	2	50	2000	
						0.134	0.04											
						0.135	0.03											
L.S.R.-lake outflow	0.12	0.2	0.005	0.32	0.02	0.07	0.03		0.64	L.02		0.0095		0.0126	L1.	10	L1.	0.5
Slave Lake STP (grab)	2.28	0.9	0.024	1.97	0.017	0.05	18		25.6	0.79	4.1		5.45		L1.	850	100	
L.S.R.-Mitsue Bridge	0.2		0.005	0.34	0.021	0.08	0.03		0.72	L.02		0.0121		0.0189	L1.	8	L1.	
L.S.R.-Driftwood R.	0.21		0.005	0.33	0.017	0.08	0.04		0.6	L.02		0.0123		0.0196				
L.S.R.-AR confluence	0.43	0.3	0.005	0.31	0.005	0.09	L.010		0.56	0.05		0.0108		0.0208	L1.	16	12000	1
AR north of Howie L.						0.129	0.03		0.4									
						0.129	0.03											
AR at Athabasca	0.4	0.2	0.006	0.67	0.002	0.14	0.04		0.38	0.03		0.0306		0.0378	L1.	28	2800	0.3
						0.136	0.01		0.34									
						0.138	0.05		0.4									
T. of Athabasca STP	2.9	1.7	0.024	1.95	0.128	0.2	19		30.4	C.57	6.2		6.87		700	10700	4400	
AR above La Biche R.	0.27	0.1	0.006	0.64	0.006	0.18	0.02		0.04	0.03		0.0253		0.0354	L1.	24	2700	
						0.143	0.04											
La Biche R.	1.49	0.2	0.011	0.66	0.004	0.4	0.43		1.6	0.11		0.0305		0.1325	L1.	4	140	
Calling R.	0.65		0.007	0.37	0.004	0.26	0.19		0.6	0.06		0.0061		0.0371	L1.	8	160	
AR near McMillan L.	1.85	0.2	0.006	0.52	0.005	0.14	0.04		0.4	0.04		0.026		0.0343	L1.	4	2200	
						0.15	0.04											
AR above Pelican R.	0.53		0.005	0.58		0.148	0.04		0.4	0.05								
						0.149	0.04											
Pelican R.	1.75		0.027	1.81	0.004	0.02	0.02		2.64	0.23		0.0239		0.0723	8	8	1600	
AR above House R.	0.31	0.2	0.006	0.47	0.006	0.17	0.04		0.34	0.03		0.0242		0.033	2	64	180	0.4
						0.164	0.03											
						0.167	0.03											
House R.	0.68		0.007	0.94	0.006	0.66	0.15		0.68	0.04		0.0232		0.0991				
AR above Buffalo Cr.			0.005									0.0204		0.0322				
Buffalo Cr.	1.26		0.016	1.74	0.006	0.73	0.06		1.04	0.08		0.0959		0.1863				
AR above Boiler Rapids	0.23		0.006	0.58	0.005	0.18	0.02		0.24	0.04		0.0195		0.029				
						0.179	0.02											

Appendix 5. Continued...

STATION	PC mg/L 06905L	O&G mg/L 06524L	PHENOLS mg/L 06537L	T&L mg/L 06551L	NO2-N mg/L 07205L	NO2+3-N mg/L 07105L	TOT. NH3-N mg/L 07505L	DISS. NH3-N mg/L 07562L	TKN-N mg/L 07015L	TPN mg/L 07906L	TDP mg/L 15105L	TDP mg/L 15114L	TP mg/L 15406L	TP mg/L 15422L	FECAL COL. #/dL 36012L	TOTAL COL. #/dL 36001L	STD. PL.CNT. #/mL 36905L	Chl-a mg/L 06715L
AR above Horse R.	0.29	0.1	0.007	0.5	0.005	0.19	0.02		0.54	0.03	0.016	0.0166	0.022	0.0265	2	4	L1.	0.3
						0.197	0.02		0.6									
						0.19	0.03		0.54									
Horse River	0.5		0.005	0.86	0.004	0.43	0.04		0.62	0.02								
Clearwater River	0.64	L.1	0.004	0.44	0.003	0.17	0.06		0.54	0.05		0.0272		0.0506	L1.	18	L1.	
						0.169	0.06											
Ft. McMurray STP	2.15	0.4	0.012	0.76	0.014	4.0	11.2		16.6	0.39	1.56		1.77		300	11000	400	
						4.1	10.7											
AR above Suncor	0.38		0.005	0.46		0.192	0.07		0.58	0.03		0.0206		0.0343	L1.	102	L1.	
						0.191	0.04											
Suncor Process Effl. (grab	4.17	3.5	0.01	0.62	0.01	0.17	0.07		0.84	0.2	0.089		0.235					
Steepbank River	0.72		0.004	0.79	0.004	0.35	0.06		0.7	0.03		0.0138		0.0593				
Muskeg River	0.43		0.008	1.5	0.004	0.22	0.15		1.28	0.02		0.0159		0.0326				
Mackay River	0.33		0.012	1.74	0.012	0.48	0.03		1.14	0.02		0.0829		0.1284				
Ells River	0.35		0.007	0.89	0.002	0.4	0.01		0.84	0.03		0.0249		0.0449				
AR near Bitumount	0.33	0.4	0.005	0.48	0.004	0.2	0.05		0.48	0.04		0.0223		0.0373	2	64	3460	
						0.208	0.02											
AR above Firebag R.	0.51		0.004	0.51		0.187	0.04		0.52	0.05		0.0216		0.0362	4	64	260	
						0.184	0.04											
Firebag River	0.37			0.45	0.003	0.185		0.048	0.26	0.03			0.049					0.1
	0.2		0.003	0.48	0.003	0.2	0.01		0.54	0.02		0.0386		0.0563				0.1
						0.165	0.02											
AR at Old Fort	0.51	0.4	0.005	0.49	0.005	0.2	0.05		0.54	0.05		0.0217		0.0392	L1.	44	220	0.4
						0.188	0.04		0.62	0.05			0.043					0.4
						0.193	0.04		0.64									
	0.43		0.005	0.52	0.006	0.2		0.088	0.39									
Richardson River	0.68		0.003	0.49	0.003	0.11	0.03		0.5	0.05		0.0409		0.067				0.6
	1.17		0.003	0.48	0.003	0.1		0.056	0.2	0.07			0.058					0.6
AR - Big Point Chan.	0.17		0.005	0.53	0.006	0.19	0.04		0.48	0.02		0.024		0.0378				
AR - Goose Is. Chan.	0.42		0.004	0.56		0.206	0.04		0.5	0.03		0.0186		0.0345				

Appendix 5. Continued...

STATION	TOTAL Al mg/L 13030L	TOTAL As mg/L 33011L	TOTAL Ba mg/L 56009L	DISS. Be mg/L 04103L	TOTAL Cd mg/L 48009L	TOTAL Co mg/L 27009L	TOTAL Cr mg/L 24009L	TOTAL Cu mg/L 29009L	TOTAL Fe mg/L 26009L	TOTAL Hg mg/L 80015L	TOTAL Mn mg/L 25003L	TOTAL Mo mg/L 42009L	TOTAL Ni mg/L 28009L	EXTR. Pb mg/L 82302L	TOTAL Se mg/L 34011L	TOTAL V mg/L 23009L	TOTAL Zn mg/L 30009L
AR above Hinton	0.023	0.0005	0.056	L.001	0.001	0.001	0.003	0.001	0.312	L.0001	0.011	0.001	0.003	L.002	L.0001	0.004	0.002
	0.033	0.0005	0.057	L.001	0.001	0.001	0.003	0.003	0.439	L.0001	0.016	0.001	0.004	0.002	L.0001	0.004	0.003
	0.033	0.0004	0.057	L.001	0.002	0.002	0.004	0.002	0.428	L.0001	0.015	0.002	0.004	0.002	L.0001	0.003	0.007
Hinton Comb. Effl.	0.192	0.001	0.098	L.001	0.003	0.003	0.011	0.024	0.276	L.0001	0.628	0.004	0.006	0.007	L.0001	0.006	0.065
AR 6 km ds HCE (comp)	0.033	0.0002	0.058	L.001	0.002	L.001	0.003	0.001	0.136		0.026	0.002	0.004	0.002	L.0001	0.003	0.002
AR 21 km ds HCE	0.075	0.0003	0.058	L.001	0.002	0.001	0.003	0.002	0.196	L.0001	0.028	0.002	0.004	0.003	L.0001	0.003	0.003
Oldman Creek	0.015		0.061	L.001	L.001	L.001	0.004	L.001	0.064	L.0001	0.004	0.002	0.002	L.002		0.004	L.001
Spring 1	0.01		0.115	L.001	0.002	L.001	0.005	L.001	0.007	L.0001	L.001	0.002	0.003	0.006		0.003	L.001
AR above Berland	0.032		0.056	L.001	0.001	L.001	0.004	L.001	0.054	L.0001	0.008	0.002	0.003	L.002		0.004	L.001
Berland River	L.002		0.114	L.001	0.001	0.001	0.004	L.001	0.063	L.0001	0.002	0.003	0.004	L.002		0.004	L.001
Spring 2	0.015		0.127	L.001	0.002	0.001	0.005	L.001	0.17	L.0001	0.026	0.002	0.002	L.002		0.004	L.001
Marsh Head Creek	0.01		0.122	L.001	0.002	0.001	0.016	0.001	0.206	L.0001	0.036	0.003	0.007	L.002		0.004	0.005
Pine Creek	0.226		0.076	L.001	0.001	L.001	0.004	L.001	0.456	L.0001	0.057	0.002	0.004	L.002		0.003	0.004
Spring 3	0.015		0.14	L.001	0.001	L.001	0.006	0.001	0.454	L.0001	0.089	0.001	0.004	L.002		0.003	0.003
Two Creek	0.021		0.143	L.001	0.002	L.001	0.005	0.002	0.214	L.0001	0.056	0.002	0.004	L.002		0.003	0.009
Windfall Creek	0.021		0.081	L.001	L.001	L.001	0.004	L.001	0.745	L.0001	0.107	0.001	0.003	L.002		0.002	0.003
AR above Whitecourt	0.038	0.0003	0.071	L.001	L.001	0.001	0.005	L.001	0.094	L.0001	0.011	0.002	0.004	L.002	L.0001	0.004	0.004
McLeod River	0.015	0.0003	0.123	L.001	0.004	0.002	0.005	0.001	0.104	L.0001	0.01	0.004	0.004	0.004	0.0003	0.005	0.005
M.W. Effluent	0.015	0.0019	0.17	L.001	0.021	0.013	0.029	0.04	1.27	L.0001	1.14	0.012	0.029	L.002	L.0001	0.024	0.412
Whitecourt STP (grab)	0.012	0.0011	0.131	L.001	0.004	0.003	0.006	0.009	0.054	L.0001	0.085	0.003	0.008	L.002	0.0003	0.005	0.062
AR 10 km ds McLeod	0.015	0.0002	0.078	L.001	0.004	0.002	0.005	0.001	0.09	L.0001	0.011	0.002	0.002	L.002	0.0004	0.005	0.001
AR at Blue Ridge Br.	0.027	0.0003	0.083	L.001	0.004	0.002	0.005	0.001	0.142	L.0001	0.018	0.003	0.005	L.002	0.0004	0.005	0.002
AR at Ft. Assin.	0.015	0.0002	0.084	L.001	0.001	0.002	0.007	0.001	0.163	L.0001	0.014	0.003	0.004	0.004	L.0001	0.004	0.007
Freeman R.-west mouth	0.021	0.0012	0.127	L.001	0.001	0.002	0.006	0.002	0.887	L.0001	0.147	0.003	0.005	L.002	L.0001	0.003	0.006
Pembina R.	0.021	0.0009	0.17	L.001	L.001	0.002	0.007	0.002	0.538	L.0001	0.072	0.004	0.005	L.002	L.0001	0.006	0.008
AR above Smith, @ Hwy 2	0.007	0.0002	0.095	L.001	0.002	0.002	0.007	0.003	0.17	L.0001	0.01	0.002	0.004	0.002	0.0001	0.005	0.007
L.S.R.-lake outflow	0.01	0.0013	0.064	L.001	L.001	L.001	0.004	0.002	0.065	L.0001	0.005	L.001	0.003	L.002	L.0001	L.002	0.004
Slave Lake STP (grab)	0.021	0.0038	0.033	L.001	0.002	0.003	0.006	0.011	1.975	L.0001	0.367	0.002	0.006	L.002	L.0001	0.003	0.047
L.S.R.-Mitsue Bridge	0.015	0.0013	0.063	L.001	L.001	L.001	0.004	0.002	0.109	L.0001	0.012	L.001	0.004	L.002	L.0001	L.002	0.004
L.S.R.-AR confluence	0.015	0.001	0.065	L.001	L.001	L.001	0.004	0.003	0.186	L.0001	0.039	L.001	0.003	L.002	L.0001	L.002	0.005
AR at Athabasca	0.017	0.0005	0.09	L.001	0.001	L.001	0.006	0.003	0.147	L.0001	0.008	0.001	0.003	L.002	L.0001	0.003	0.006
T. of Athabasca STP	0.019	0.0011	0.041	L.001	0.001	0.002	0.005	0.01	0.374	L.0001	0.081	0.004	0.008	0.005	L.0001	0.004	0.064
AR above La Biche R.	0.012	0.0015	0.085	L.001	0.002	0.002	0.004	0.002	0.133	L.0001	0.006	0.002	0.004	L.002	L.0001	0.003	0.005
La Biche R.	0.047	0.0034	0.068	L.001	0.002	0.002	0.006	0.002	1.356	L.0001	0.439	0.002	0.006	0.002	L.0001	0.005	0.016
Calling R.	0.049	0.0023	0.128	L.001	0.002	0.002	0.005	0.002	0.639	L.0001	0.132	0.003	0.005	L.002	L.0001	0.005	0.005
AR near McMillan L.	0.018	0.0015	0.086	L.001	0.001	0.001	0.005	0.002	0.151	L.0001	0.007	0.002	0.005	0.002	L.0001	0.003	0.005
Pelican R.	0.041	0.0027	0.051	L.001	L.001	0.002	0.004	0.001	1.687	L.0001	1.827	0.001	0.003	L.002	L.0001	0.003	0.006
AR above House R.	0.019	0.0008	0.087	L.001	0.001	L.001	0.005	0.003	0.161	L.0001	0.013	0.002	0.004	L.002	L.0001	0.003	0.007
House R.	0.048	0.0014	0.052	L.001	0.002	0.002	0.005	0.002	1.388	L.0001	0.27	0.003	0.007	L.002	L.0001	0.004	0.009
Buffalo Cr.	0.013	0.0015	0.054	L.001	0.003	0.003	0.006	0.002	2.396	L.0001	0.358	0.002	0.007	L.002	L.0001	0.006	0.008

Appendix 5. Continued...

STATION	TOTAL Al mg/L 13030L	TOTAL As mg/L 33011L	TOTAL Ba mg/L 56009L	DISS. Be mg/L 04103L	TOTAL Cd mg/L 48009L	TOTAL Co mg/L 27009L	TOTAL Cr mg/L 24009L	TOTAL Cu mg/L 29009L	TOTAL Fe mg/L 26009L	TOTAL Hg mg/L 80015L	TOTAL Mn mg/L 25003L	TOTAL Mo mg/L 42009L	TOTAL Ni mg/L 28009L	EXTR. Pb mg/L 82302L	TOTAL Se mg/L 34011L	TOTAL V mg/L 23009L	TOTAL Zn mg/L 30009L
AR above Boiler Rapids	0.013	0.0008	0.087	L.001	0.001	0.001	0.005	0.002	0.155	L.0001	0.006	0.002	0.004	L.002	L.0001	0.003	0.006
AR above Horse R.	0.013	0.0006	0.089	L.001	0.001	L.001	0.004	0.003	0.174	L.0001	0.004	0.003	0.004	L.002	L.0001	0.004	0.005
Horse River	0.013	0.0008	0.071	L.001	0.002	0.002	0.005	0.002	0.779	L.0001	0.031	0.003	0.006	L.002	L.0001	0.005	0.014
Clearwater River	0.021	0.0007	0.02	L.001	L.001	L.001	0.002	0.003	0.883	L.0001	0.052	0.001	0.002	L.002	L.0001	L.002	0.012
Ft. McMurray STP (grab)	0.175	0.0013	0.01	L.001	0.002	0.002	0.005	0.004	0.086	L.0001	0.027	0.003	0.013	0.002	L.0001	0.004	0.052
Suncor Process Effl. (grab	0.231	0.0039	0.084	0.001	0.002	0.005	0.006	0.007	0.719	L.0001	0.077	0.385	0.148	L.002	L.0001	0.289	0.016
Steepbank River	0.013	0.0006	0.073	L.001	0.002	0.001	0.005	0.002	0.83	L.0001	0.018	0.003	0.005	L.002	L.0001	0.005	0.012
Muskeg River	0.007	0.0006	0.052	L.001	0.001	0.001	0.004	L.001	1.304	L.0001	0.221	0.001	0.004	0.002	L.0001	0.004	0.008
Mackay River	0.019	0.0013	0.048	L.001	0.002	0.002	0.005	0.002	1.952	L.0001	0.02	0.003	0.006	L.002	L.0001	0.005	0.012
Ells River	0.024	0.0009	0.04	L.001	L.001	L.001	0.002	0.002	0.572	L.0001	0.015	0.[illegible]2	0.004	L.002	L.0001	0.002	0.01
AR near Bitumount	0.013	0.0006	0.066	L.001	L.001	L.001	0.003	0.002	0.473	L.0001	0.021	0.[illegible]	0.004	0.002	L.0001	0.004	0.011
Firebag River	L.002	0.0003	0.03	L.001	0.001	L.001	0.002	0.002	0.607	L.0001	0.035	0.[illegible]2	0.002	0.017	L.0001	0.002	0.003
	L.002	0.0003	0.03	L.001	0.001	L.001	0.002	L.001	0.619	L.0001	0.035	L.001	0.002	0.012	L.0001	0.002	0.002
AR at Old Fort	L.002	0.0005	0.065	L.001	0.001	L.001	0.003	0.002	0.597	L.0001	0.046	0.002	0.003	L.002	L.0001	0.003	0.004
	L.002	0.0004	0.063	L.001	0.001	L.001	0.002	0.002	0.498	L.0001	0.04	0.002	0.001	0.009	L.0001	0.003	0.001
Richardson River	L.002	0.0005	0.013	L.001	L.001	L.001	L.001	L.001	0.704	L.0001	0.049	0.001	0.001	L.002	L.0001	L.002	0.002
	L.002	0.0005	0.014	L.001	0.001	L.001	0.002	0.002	0.815		0.054	L.001	0.004	L.002	L.0001	L.002	0.003
AR - Big Point Chan.	L.002	0.0005	0.057	L.001	0.001	L.001	0.003	0.002	0.55	L.0001	0.035	0.001	0.004	L.002	L.0001	0.003	0.004

APPENDIX 6. Trace organics in the Athabasca River and the Hinton Combined Effluent (HCE), Survey 88-1.

COMPOUND	above Hinton	HCE*	6 km above	21 km d/s HCE	above Berland River	above White-court	above Smith	at Athabasca
	n = 2							
ORGANIC PRIORITY POLLUTANTS								
Volatiles-Chloroform		12	1.X			1.X		
Semivolatiles								
OTHER TRACE ORGANICS								
Resin acids								
Sandaracopimaric acid		740	5-50					
Phenolics								
3,4,5-trichloroguaiacol		48			0.1-0.5			
Guaiacol		564	1-5		0.1-0.5			
Methoxyphenol (all isomers)			<15			0.1-0.5		
Methyl-tert-butyl-phenol		<15			0.1-0.5			
Dimethoxybenzene		34	0.1-0.5		0.1-0.5			
Vanillin		19	0.1-0.5		0.1-0.5			
Acetosyringol (all isomers)			15	5-50		0.1-0.5		
Other Acids								
m-toluic acid		25	0.1-0.5					
Base/Neutrals								
1,1-dichlorodimethyl sulphone			44	1-5	0.1-0.5	0.1-0.5	0.1-0.5	0.1-0.5
Dimethyl sulphone		<15	0.1-0.5					
Benzylmethyl sulphide		25	0.1-0.5					
Dimethyl trisulphide		<25	0.1-0.5		0.1-0.5			
Diethyl thiophene		<20		0.1-0.5				
Methylethyl thiophene		79	1-5		0.1-0.5			
Methyl-3-thiophenecarboxylate			<20			0.1-0.5		
1-methyl-4-(1-methylethyl)-benzene			58	1-5		0.1-0.5		
Methylpropyl benzene		<20	0.1-0.5		0.1-0.5			
Chloromethyl cyclohexadiene			27	0.1-0.5		0.1-0.5		
Allocimene		<25	0.1-0.5					
Delta-3-carene		<25	1-5					
P-Cymen-8-ol		600	5-50					
Dihydroxycyclohexadiene		<25	0.1-0.5		0.1-0.5			
1,2-dimethyl cyclohexene		<25		0.1-0.5				
2,3-dimethyl-2-cyclopentenone (all isomers)			<25	1-5				
Dimethyl hexadiene		<25	0.1-0.5		0.1-0.5			
2-butanone, 3-phenyl-cyclo-hexanone			-	0.1-0.5				
Dimethyl cyclohexadiene		-			1-5			
2-cyclohexen-1-one		-		0.1-0.5				
1-(2-thienyl)-ethanone		-		0.1-0.5				
Fenchone		64	5-50		0.1-0.5			
Limonene		130	1-5	0.1-0.5	0.1-0.5			
Phellandrene (all isomers)			20	1-5				
Sabinene		120			0.1-0.5			
2,3,4-trimethyl-2-cyclopentene-1-one			110			0.1-0.5		
Others								
Benzothiazole (all isomers)			<20	0.1-0.5		0.1-0.5		
Nanool		<100	0.1-0.5	0.1-0.5	0.1-0.5			

*For HCE, additional data are included in Appendix 9.

Results as µg/L. Only compounds detected in the river are listed. Detection limits for priority pollutants are indicated in Appendix 8.
X estimated, less than method detection limit, but greater than zero.
T trace amount detected
blanks indicate not detected
dashes indicate not sampled or not analyzed

Appendix 6. Trace organics in the Athabasca River and selected effluents to the river, Survey 89-1.

Compound	u/s Hinton	HCE	21km d/s HCE	36km d/s HCE	u/s Berland River	u/s Whitecourt	MWPLE	10km d/s McLeod River	at Blue Ridge	at Ft. Assiniboine	u/s Smith	at Athabasca	at McMillan Lake	u/s Horse River	Suncor Process Effl.	at Old Fort
ORGANIC PRIORITY POLLUTANTS																
Extractables																
2,4-Dichlorophenol		8														
2,4,6,-Trichlorphenol		20				0.X										
Benzoic acid			0.X	0.X												
Hexadecanoic acid				1.X		1.X	125						1.X	1.X		2.X
Purgeables																
1,1,1-Trichloroethane															2	
1,2-Dichloroethane	0.X			0.X	0.X	0.X		0.X	0.X							
Carbontetrachloride															4	
Chloroform		53	4	3	2	1		1.X	1.X	1.X	1.X	1.X	0.X	0.X	2	
Ethylbenzene								0.X								
m,p-Xylene								0.X								
Styrene							30									
Toluene		7	0.X						0.X							
OTHER TRACE ORGANICS																
Resin Acids																
Abietic acid		14					305									
Dehydroabietic acid		17					610									
Dichlorodehydroabietic acid		50	0.X													
Isopimaric acid		10					323									
Monochlorodehydroabietic acid		53														
Neoabietic acid							54									
Palustric/Levopimaric acid							242									
Primaric acid		20					18									
Sandaracopimaric acid		5					25									
Other acids																
4-(1-methylethyl benzoic acid)							30									
9,12-octadecadienoic acid(2 isomers)							340									
Chlorobenzoic acid						0.X										
Dodecanoic acid													0.X			
Heptadecanoic acid							10									
Isopropylbenzoic acid		14														
Linoleic acid		18					96									
m-Toluic acid			0.X													
Nonanoic acid													0.X			
Oleic acid			0.X	0.X												
Oleic/Linolenic acid		22					59									
Stearic acid			0.X	0.X												
Tetradecanoic acid				0.X									0.X			0.X
Tridecanoic acid							25									

Appendix 6. Survey 89-1, Continued...

Compound	u/s Hinton	HCE	21km d/s HCE	36km d/s HCE	u/s Berland River	u/s Whitecourt	MWPLE	10km d/s McLeod River	at Blue Ridge	at Ft. Assiniboine	u/s Smith	at Athabasca	at McMillan Lake	u/s Horse River	Suncor Process Effl.	at Old Fort
Phenolics																
Dichloroguaicol		7	0.X	0.X												
Guaicol		5														
Tetrachloroguaicol		12	0.X	0.X		0.X										
Trichloroguaicol		45	0.X	0.X	0.X	1.X										
Vanillin				0.X	0.X			0.X	0.X	0.X		0.X				
Base/Neutral Fraction																
1-H-Inden-1-one,2,3-dihydro-3,3,4,7-tetramethyl							60									
1-Methyl-2 benzene							130									
2-Pentylfuran							20									
4-Trimethyl-3-cyclohexene-1-methanol							200									
5-Nonen-2-one							65									
Acetophenone							150									
alpha-Pinene and isomers							175									
alpha-Terpineol							200									
Camphor (2 isomers)							90									
Dichlorodimethyl sulphone			0.X	0.X	1.X	2.X		1.X	1.X	1.X	1.X	1.X	1.X	1.X		
Dimethoxybenzene (Veratrole)		5														
Dimethylcyclopentenone		36	0.X	0.X	0.X											
Dimethyldisulfide		6														
Dimethyltrisulfide		T														
Isopropylbenzene methanol		70														
Methylbenzene methanol							30									
Methylisopropenylbenzene				0.X												
p-Cymen-8-ol			0.X													
Terpineol		80														
Trichlorodifluoroethane		23														
Trimethyldimethylethyl - ethylbenzene methanol							950									
Trimethylcyclopentenones		42		0.X												
Acid Fraction																
4-Hydroxy-3-methoxybenzaldehyde							20									
2-Pentylfuran							20									
Purgeables																
2,2,3-Trimethylhexane							10									
Methyl cyclohexadiene		8														
Methyl cyclohexane		T														
Methyl pentane							30									
Methylene cyclohexane		14					30									

Appendix 6. Trace organics in the Athabasca River and selected effluents to the river, Survey 89-2

Compound	AR above Whitecourt	Millar Western Effluent	AR at Ft.Assiniboine	AR above Smith
ORGANIC PRIORITY POLLUTANTS				
Extractables				
2,4,6,-Trichlorophenol	0.X		1.X	
Hexadecanoic acid	1.X		1.X	1.X
Purgeables				
Chloroform	1.X			0.X
Styrene		2		
OTHER TRACE ORGANICS				
Resin Acids				
Primaric acid		2.8		
Phenolics				
Tetrachloroguaicol	0.X			
Trichloroguaicol	1.X		1.X	0.X
Vanillin		110		
Other acids				
4-Hydroxy, 3,5-dimethoxy benzoic acid		55		
Chlorobenzoic acid	0.X			
Linoleic acid		28		
Methylethyl benzoic acid		45		
Oleic/Linolenic acid		28		
Base/Neutral Fraction				
Dichlorodimethyl sulphone	2.X		2.X	2.X
Diacetyl benzofuran		830		
Acid Fraction				
Dipropyl benzene		14		
Purgeables				
Pinene and isomers		5		

Appendix 6. Trace organics in the Athabasca River and selected effluents to the river, Suryey 89-3.

Compound	u/s Hinton	HCE	21km d/s HCE	36km d/s HCE	u/s Berland River	u/s White-court	MWPLE	White-court STP	10km d/ McLeod River	at Blue Ridge	at Ft. Assini-boine	u/s Smith	at Atha-basca	at Mc-Millan Lake	u/s Horse River	Suncor Process Effl.	at Old Fort
ORGANIC PRIORITY POLLUTANTS																	
Extractables																	
2,4-Dimethylphenol																1.X	
2,4,6,-Trichlorphenol		12		0.X													
Benzoic acid			0.X	0.X	0.X	0.X											
Benzo(a)anthracene																1.X	
Chrysene																0.X	
Fluorene																0.X	
Fluoroanthene																0.X	
Hexadecanoic acid			2.X		2.X	2.X	90	10	2	1.X	1.X						
Phenanthrene																0.X	
Pyrene																1.X	
Purgeables																	
1,1,1-Trichloroethane																2	
1,4-Dichlorobenzene								0.X									
Carbontetrachloride																2	
Chloroform		46		2				2	1.X	1.X	1.X	1.X			0.X	1	0.X
Styrene							T										
Toluene		7															
OTHER TRACE ORGANICS																	
Resin Acids																	
Abietic acid							13					-	-	-	-	-	-
Dehydroabietic acid		9					73					-	-	-	-	-	-
Dichlorodehydroabietic acid		6										-	-	-	-	-	-
Isopimaric acid		7					40					-	-	-	-	-	-
Monochlorodehydroabietic acid		12										-	-	-	-	-	-
Palustric/Levopimeric acid							32					-	-	-	-	-	-
Primaric acid		8					18					-	-	-	-	-	-
Sandaracopimeric acid							24					-	-	-	-	-	-
Other acids																	
Alkali fatty acids								10.X				-	-	-	-	-	-
Chlorobenzoic acid			0.X	1.X								-	-	-	-	-	-
Dodecanoic acid				1.X								-	-	-	-	-	-
Linoleic acid		8					181					-	-	-	-	-	-
Octadecanoic acid							110					-	-	-	-	-	-
Oleic/Linolenic acid		16					432					-	-	-	-	-	-
Pentadecanoic acid							33					-	-	-	-	-	-

Appendix 6. Survey 89-3, Continued...

Compound	u/s Hinton	HCE	21km d/s HCE	36km d/s HCE	u/s Berland River	u/s White-court	MWPLE	White-court STP	10km d/ McLeod River	at Blue Ridge	at Ft. Assini-boine	u/s Smith	at Atha-basca	at Mc-Millan Lake	u/s Horse River	Suncor Effl.	at Old Fort
Phenols																	
Guaicol			1.X									-	-	-	-	-	-
Tetrachloroguaicol		16	0.X	0.X	1.X	1.X						-	-	-	-	-	-
Trichloroguaicol		17	0.X	1.X	1.X	1.X			0.X			-	-	-	-	-	-
Vanillin		11					30					-	-	-	-	-	-
Base/Neutral Fraction																	
1-(4-Hydroxy-3,5-dimethoxyphenol)-ethanone		5										-	-	-	-	-	-
1H-Indole							5					-	-	-	-	-	-
2-Chloro-1-phenyl ethanone		18										-	-	-	-	-	-
Acetophenone		10	0.X									-	-	-	-	-	-
Diacetyl benzofuran							30					-	-	-	-	-	-
Dichlorodimethyl sulphone			3.X	3.X	2.X	2.X			2.X	1.X	1.X	-	-	-	-	-	-
Dihyroxyacetophenone		10										-	-	-	-	-	-
Dimethoxybenzene (Veratrole)		17	0.X									-	-	-	-	-	-
Dimethylcyclohexene			0.X	1.X	0.X				0.X			-	-	-	-	-	-
Dimethylcyclopentanone		30										-	-	-	-	-	-
Dimethyldisulfide		22	2.X	2.X	2.X							-	-	-	-	-	-
Dimethyltrisulfide		8.6	0.X	0.X								-	-	-	-	-	-
Methylcyclopentanone		9										-	-	-	-	-	-
p-Cymen-8-ol			0.X									-	-	-	-	-	-
Tributyl phosphate				0.X								-	-	-	-	-	-
Trichlorodifluroethane		43										-	-	-	-	-	-
Trimethylcyclopentenones		74	0.X									-	-	-	-	-	-
Acid Fraction																	
Tetra,1,1,-dioxide thiophene		14										-	-	-	-	-	-
Purgeables																	
Methyl cyclohexadiene		6										-	-	-	-	-	-
Methyl cyclohexane		4										-	-	-	-	-	-

APPENDIX 7 Water Quality Parameters and Analytical Methods

Parameter	Container	Preservation	Analytical Code	Analytical Method Or Instrument
Field Analysis				
Temperature			02061F	Field meter
pH			10301F	Field meter
Conductance			02041F	Field meter
Oxygen, dissolved			08101F	Azide-Winkler method
Lab Analysis				
pH	P	Cool to 4°C	10301L	Meter
Ca	P	Cool to 4°C	20110L	Automated atomic absorption
Mg	P	Cool to 4°C	12303L	Atomic absorption, direct aspiration
Na	P	Cool to 4°C	11103L	Flame photometer
K	P	Cool to 4°C	19103L	Flame photometry, internal standard
HCO_3			06201L	Calculated
Cl	P	Cool to 4°C	17203L	Colourimetry, ferric ammonium sulfate and mercuric thiocyanate
SO_4	P	Cool to 4°C	16306L	Colourimetry, $BaCl_2$ and methylthymol blue
SiO_2	P	Cool to 4°C	14102L	Heteropoly blue colourimetry
F	P	Cool to 4°C	09107L	Automated potentiometric method
Conductance	P	Cool to 4°C	02041L	Meter
Total dissolved solids			00205L	Calculated
T. hardness			10602L	Calculated, as $CaCO_3$
Total alkalinity	P	Cool to 4°C	10101L	Potentiometric titration
Total residue			10474L	Calculated
Filterable residue	P	Cool to 4°C	10453L	Gravimetric
Non filterable Residue	P	Cool to 4°C	10407L	Gravimetric (0.45 mm filter)
NO_2+NO_3-N	P	Cool to 4°C	07105L	Colourimetry on autoanalyzer
Nitrite-N	P	Cool to 4°C	07205L	Colourimetry on autoanalyzer
Ammonia-N	P	2ml 5% H_2SO_4	07562L	Colourimetric analysis
Total Phosphorous	P	2ml 5% H_2SO_4	15421L	Colourimetry on autoanalyzer
Total Kjeldahl Nitrogen	P	2ml 5% H_2SO_4	07021L	Colourimetry on autoanalyzer
T. Nitrogen, particulate	P		07906L	Thermal conductivity
Biochemical oxygen demand	G	Cool to 4°C	08202L	5 day, 20°C
Chemical oxygen demand	P	2ml 5% H_2SO_4	08304L	Semi-automated colourimetry
C, dissolved organic	P	Cool to 4°C	06107L	Colourimetry
C, dissolved inorganic	P	Cool to 4°C	06154L	Colourimetry
C, Total	P	Cool to 4°C	06905L	Thermal conductivity
Phenols	G	1:1 H_2SO_4	06537L	Automated 4-aminoantipyrine colourimetry

APPENDIX 7 Cont'd

Odour	G	Cool to 4°C	02001L	Threshold dilution number
Tannin and Lignin	G	Cool to 4°C	06551L	Filtered if turbid: acid colourimetry
Colour, true	G	Cool to 4°C	02022L	Spectrophotometric, Pt-Co standard (H5P method)
Oil and Grease	G	1:1 H_2SO_4	06524L	Freon extraction and IR spectrophotometry
Fe (extr)	P	Cool to 4°C	26304L	Atomic absorption, direct aspiration
Cr +6 (diss.)	P	1:1 HNO_3	24101L	Colourimetric with diphenylcarbazide
Hg (total)	P	HNO_3-$K_2Cr_2O_7$	80015L	Flameless atomic absorption
Co (total)	P	1:1 HNO_3	27009L	Atomic emission spectrometry (ICAP)
Cu (total)	P	1:1 HNO_3	29009L	ICAP method
Ni (total)	P	1:1 HNO_3	28009L	ICAP method
Cd (total)	P	1:1 HNO_3	48009L	ICAP method
Pb (extr.)	P	1:1 HNO_3	82302L	Atomic absorption, solvent extraction
Zn (total)	P	1:1 HNO_3	30009L	ICAP method
Mn (total)	P	1:1 HNO_3	25003L	ICAP method
Cr (total)	P	1:1 HNO_3	24009L	ICAP method
Be (extr)	P	1:1 HNO_3	04304L	Atomic absorption, solvent extraction
V (total)	P	1:1 HNO_3	23009L	ICAP method
Mo (total)	P	1:1 HNO_3	42009L	ICAP method
Al (extr)	P	1:1 HNO_3	13306L	Atomic absorption, solvent extraction
Se (total)	P	1:1 HNO_3	34005L	Goulden and Brooksbank (1974) method
As (total)	P	1:1 HNO_3	33005L	Goulden and Brooksbank (1974)
Bacteria				
Total coliforms	G	Cool to 4°C	36002L	Membrane filtration (EPS)
			36001L	Tube dilution (Prov. Lab.)
Fecal coliforms	G	Cool to 4°C	36012L	Membrane filtration (EPS)
			36011L	Tube dilution (Prov. Lab.)
Fecal streptococci	G	Cool to 4°C	36102L	Membrane filtration (EPS)
Standard plate count	G	Cool to 4°C	36905L	Agar plate at 35°C (EPS)
Toxicity		Cool to 4°C		Static 96 hr. multiple concentration LC_{50}, Rainbow Trout (Alberta Environment 1978)

P - polyethylene container G- Glass container
Analytical codes and methods: see Environment Canada (1986), and Alberta Environment (1981).

APPENDIX 7 Cont'd

Priority Pollutant Analysis Methodology

D. Smillie, Alberta Environmental Centre, Chemistry Wing

The method employed for extractable priority pollutants in the MD&RS Section is based on the EPA Method 625 and covers the analysis of a number of organics that are partitioned into an organic solvent and are amenable to capillary gas chromatography/mass spectrometry (GC/MS). The method for purgeable priority pollutants is based on EPA Method 624 and deals with organics that are purged from water onto a trap, then desorbed and analyzed by capillary GC/MS.

The surface water is collected in the field directly into pretreated one litre amber sample bottles and stored in a refrigerator at 2-5°C until the time of analysis. The entire one litre volume of sample is serially extracted with methylene chloride at a pH greater than 11 and again at a pH less than 2 using a separatory funnel. The methylene chloride extracts are dried and concentrated, ready for GC/MS analysis.

Mass spectrometric/gas chromatographic analysis permit the separation and measurement of the organics in the extract. Qualitative screening is performed on target compounds using the relative retention time and relative abundances of three characteristic ions from the GC/MS data of the components of the extract. A full identification of organics screened in this manner is performed using full reference spectra. Quantitative analysis is performed using a multi-internal standards technique in which the integrated areas of characteristic ions are utilized in the calculation. Unknown compounds are identified based on comparsion with library spectra. Quantification of these non-target compounds (those that are not listed as priority pollutants) is accomplished by comparision of response with an appropriate internal standard.

The method employed for volatile or purgeable priority pollutants is the purge-and-trap technique. A sample volume of 15 mL is purged with an inert gas, helium. A Tenax trap adsorbs the volatile organics purged out of solution. This is followed by thermal desorption of the volatiles on the trap onto a GC column, and subsequent mass spectral analysis. Qualitative and quantitative analysis are performed in the same fashion as for extractable priority pollutants.

Trace organic compounds analyzed in this study are listed in Appendices 8 and 9.

APPENDIX 8. Trace organic priority pollutants.

ALBERTA ENVIRONMENTAL CENTRE
****
ORGANICS ANALYSIS DATA SHEET

Sample Number
AEC:
User:

File No :
QT FILE :
ANALYZED :
MM/DD/YY

VOLATILE COMPOUNDS

Group_User :
Date Sampled :
Time Sampled : By:
Sample Locat :
User Comments:

AEC Proj #:
User Proj #:

Scan :
Matrix:
Human Consumption:
Dilution Factor:
Date Received:

NAQUADAT Number		ug/L	NAQUADAT Number		ug/L
95200	BENZENE	1.U	95217	trans-1,2-DICHLOROETHYLENE	1.U
95230	BROMOCHLOROMETHANE	1.U	95218	1,2-DICHLOROPROPANE	1.U
95201	BROMODICHLOROMETHANE	1.U	95219	cis-1,3-DICHLOROPROPYLENE	3.U
95202	BROMOFORM	5.U	95220	trans-1,3-DICHLOROPROPYLENE	3.U
95203	BROMOMETHANE	1.U	95221	ETHYLBENZENE	1.U
95204	CARBONTETRACHLORIDE	1.U	95222	METHYLENE CHLORIDE	20.8
95205	CHLOROBENZENE	1.U	95223	STYRENE	1.U
95206	CHLOROETHANE	1.U	95224	1,1,2,2-TETRACHLOROETHANE	1.U
95207	2-CHLOROETHOXYETHYLENE	4.U	95225	TETRACHLOROETHYLENE	3.U
95208	CHLOROFORM	1.U	95226	TOLUENE	1.U
95209	DIBROMOCHLOROMETHANE	1.U	95227	1,1,1-TRICHLOROETHANE	1.U
95211	1,2-DICHLOROBENZENE	1.U	95228	1,1,2-TRICHLOROETHANE	1.U
95212	1,3-DICHLOROBENZENE	1.U	95231	TRICHLOROETHYLENE	1.U
95213	1,4-DICHLOROBENZENE	1.U	95229	TRICHLOROFLUOROMETHANE	1.U
95214	1,1-DICHLOROETHANE	1.U	95232	VINYL CHLORIDE	30.U
95215	1,2-DICHLOROETHANE	1.U	95233	o-XYLENE	1.U
95216	1,1-DICHLOROETHYLENE	1.U	95234	m,p-XYLENE	1.U

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DATE: 1988_____

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ALBERTA ENVIRONMENTAL CENTRE

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APPENDIX 8. Concl.

ALBERTA ENVIRONMENTAL CENTRE
****
ORGANICS ANALYSIS DATA SHEET

Sample Number
AEC:
User:

File No :
QT FILE :
ANALYZED :
MM/DD/YY

SEMIVOLATILE COMPOUNDS

Group_User :
Date Sampled :
Time Sampled : By:
Sample Locat :
User Comments:

AEC Proj #:
User Proj #:

Scan :
Matrix:
Human Consumption:
Dilution Factor:
Date Received:

NAQUADAT Number		ug/L	NAQUADAT Number		ug/L
95000	BENZOIC ACID	2.U	95028	PHENANTHRENE	1.U
95001	4-CHLORO-3-METHYLPHENOL	1.U	95029	PYRENE	1.U
95002	2-CHLOROPHENOL	2.U	95031	BENZO(b)FLUORANTHENE	1.U
95003	2,4-DICHLOROPHENOL	1.U	95032	2-CHLORONAPHTHALENE	1.U
95004	2,4-DIMETHYL PHENOL	2.U	95033	HEXACHLOROBENZENE	1.U
95005	2-METHYL-4,6-DINITROPHENOL	1.U	95034	HEXACHLOROBUTADIENE	5.U
95006	2,4-DINITROPHENOL	1.U	95035	HEXACHLOROCYCLOPENTADIENE	1.U
95007	HEXADECANOIC ACID	3.U	95036	HEXACHLOROETHANE	5.U
95008	2-NITROPHENOL	1.U	95037	1,2,4-TRICHLOROBENZENE	1.U
95009	4-NITROPHENOL	1.U	95030	ISOPHORONE	1.U
95010	PENTACHLOROPHENOL	1.U	95038	BENZIDINE	2.U
95011	PHENOL	1.U	95039	2,4-DINITROTOLUENE	1.U
95012	2,4,5-TRICHLOROPHENOL	1.U	95040	2,6-DINITROTOLUENE	1.U
95013	2,4,6-TRICHLOROPHENOL	1.U	95041	1,2-DIPHENYLHYDRAZINE	1.U
95014	ACENAPHTHENE	1.U	95042	NITROBENZENE	1.U
95015	ACENAPHTHYLENE	1.U	95043	N-NITROSODIPHENYLAMINE	1.U
95016	ANTHRACENE	1.U	95044	N-NITROSO-DI-n-PROPYLAMINE	2.U
95017	BENZO(a)ANTHRACENE	1.U	95045	4-BROMOPHENYL PHENYL ETHER	1.U
95018	BENZO(k)FLUORANTHENE	1.U	95046	BIS(2-CHLOROETHOXY)METHANE	1.U
95019	BENZO(ghi)PERYLENE	2.U	95047	BIS(2-CHLOROETHYL)ETHER	1.U
95020	BENZO(a)PYRENE	1.U	95048	BIS(2-CHLOROISOPROPYL)ETHER	1.U
95021	CHRYSENE	1.U	95049	4-CHLOROPHENYL PHENYL ETHER	1.U
95022	DIBENZO(ah)ANTHRACENE	5.U	95050	BUTYLBENZYLPHTHALATE	1.U
95023	FLUORANTHENE	1.U	95051	DIBUTYLPHTHALATE	1.U
95024	FLUORENE	1.U	95052	DIETHYLPHTHALATE	1.U
95025	INDENO(1,2,3-cd)PYRENE	1.U	95053	DIMETHYLPHTHALATE	1.U
95026	NAPHTHALENE	1.U	95054	DI-n-OCTYLPHTHALATE	1.U
95027	PERYLENE	1.U	95055	BIS(2-ETHYLHEXYL)PHTHALATE	1.U

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APPENDIX 9. Tentatively identified semivolatile organic contaminants analyzed by AEC and selected results for the HCE.

	19/02/87	24/06/87	02/02/88
RESIN ACIDS			
Chlorinated			
Chlorodehydroabietic acid, methyl ester #1.(30)			
Chlorodehydroabietic acid, methyl ester #2.(30)			30
Dichlorodehydroabietic acid, methyl ester.(30)			
Non-chlorinated			
Abietic acid.(200)			
Abietic acid, methyl ester.(25)			
Dehydroabietic acid.(200)			
Dehydroabietic acid, methyl ester.(25)			
Isopimaric acid.(200)			250
Isopimaric acid, methyl ester.(25)			
Levopimaric acid.(200)			
Levopimaric acid, methyl ester.(25)			
Neoabietic acid, methyl ester.(25)			
Palustric acid, methyl ester.(25)			
Sandaracopimaric acid (200)			
Sandaracopimaric acid, methyl ester #1.(25)			
Sandaracopimaric acid, methyl ester #2.(25)			
PHENOLICS			
Chlorinated			
Trichlorophenol #1.(15)			
Trichlorophenol #2.(15)			
2,3,4,5-Tetrachlorophenol.(15)			
4-Chlorocatechol.(30)			
4-Chlorocatechol, methyl ester (4-chloroguaiacol).(15)			
Tetrachlorocatechol.(40)			
4,5-Dichloroguaiacol.(20)			
Dichloroguaiacol.(20)			
3,4,5-Trichloroguaiacol.(20)			48
Trichloroguaiacol.(20)			
Trichloroguaiacol #2.(20)			
Trichloroguaiacol #3.(20)			
Tetrachloroguaiacol.(20)		21	
4,5-Dichloroveratrole.(15)			
3,4,5-Trichloroveratrole.(15)			36
4,5,6-Trichloromethoxyveratrole.(15)			
1,2,3,4-Tetrachloro-5,6-veratrole.(15)		15	28
Tetrachloroveratrole.(15)			
4-Chloro-m-cresol.(15)			
1,3,5-Trichloro-2-methoxybenzene.(15)	35		42
Tetrachlorophenolic, M>=246.(15)			
Non-chlorinated			
Guaicol	NA	NA	564
Methoxy phenol #2.(15)	260		
Alkylphenol M=168.(15)			
Methyl tert-butyl phenol.(15)			
Veratrole.(15)	160		200
Dimethoxybenzene.(15)	240		34
Ethylmethyl phenol.(15)	72		15
4-Ethyl guaiacol.(15)			15
4-Acetoguaiacol.(15)	70		71
4,6-Dinitro-o-cresol.(15)			
Vanillin.(15)			19
Acetosyringol.(15)			15
Methoxy substituted phenol.(15)	590	94	

APPENDIX 9 CONTINUED

	19/02/87	24/06/87	02/02/88
OTHER ACIDS			
Chlorinated Aromatics			
2-Chlorobenzoic acid.(20)			20
2-Chlorobenzoic acid, methyl ester.(15)			
4-Chlorobenzoic acid, methyl ester.(15)			
2,5-Dichlorobenzoic acid, methyl ester.(15)			
3,6-Dichloro-2-methoxy benzoic acid, methyl ester.(15)			
Non-chlorinated Aromatics			
1-Naphthoic acid.(50)			
m-Toluic acid.(25)	97		25
m-Toluic acid, methyl ester.(10)			
Chlorinated aliphatic acids			
Trichloroacetic acid, methyl ester.(15)			
2,3-Dichloro-2-propanoic acid.(25)			
Non-chlorinated aliphatic acids			
Camphorocarboxylic acid.(25)			
Dicarboxylic acid, MW=166.(25)			
Dicarboxylic acid, MW=188.(25)			
Oleic acid.(200)		E130	
Stearic acid.(200)			
Stearic acid, methyl ester.(25)			
BASE/NEUTRALS			
Chlorinated Sulphones			
Chlorosulphone MW>109.(15)	E12		
Chlorosulphone MW=158.(15)			
1,1-Dichlorodimethyl sulphone.(15)	460	180	44
Dichloromethyl sulphone.(15)			
Dichlorodimethyl sulphone.(15)			
Trichlorodimethyl sulphone.(15)			50
Non-chlorinated Sulphones			
Dimethyl sulphone.(15)	51	28	
Ethyl sulphone.(15)			
Chlorinated sulphides			
2-Chloroethylmethyl sulphide.(25)			
Non-chlorinated sulphides			
Benzylmethyl sulphide.(25)	77		25
Diphenyl sulphide.(25)			
Dimethyl trisulphide.(25)	E22		
Ethyl disulphide.(25)			
Ethyl trisulphide.(25)			
Chlorinated thiophenes			
2-Chlorothiophene.(20)			
2,5-Dichlorothiophene.(20)			
Non-chlorinated thiophenes			
Aceto thiophene.(20)			
Diethyl thiophene.(20)		21	
Ethylaceto thiophene.(20)	E16		
Methylethyl acetothiophene.(20)	E11		
Methyl-5-methyl-2-thiophene carboxylate.(20)	33		47
Methylethyl thiophene.(20)	87		79
Methyl-3-thiophene carboxylate.(20)			
1-(2-Thienyl) thiophene.(20)	42		79

APPENDIX 9 CONTINUED

	19/02/87	24/06/87	02/02/88
Chlorinated aromatic B/N			
3-Chlorobenzaldehyde.(20)	77		
4-Chlorobenzaldehyde.(20)			
4-Chlorophenyl phenyl ether (20)			
2-Chlorobenzyl alcohol.(20)			
2,4-Dichlorobenzyl alcohol.(20)			
2-Chloronaphthalene.(20)			
2,3-Dichlorobenzidene.(50)			
2,4-Dichlorotoluene.(20)			
3,4-Dichloro-2-naphthelenol.(20)			
m-Chlorotoluene.(20)			
Non-chlorinated Aromatic B/N			
Alkyl benzene #1.(20)			
Alkyl benzene #2.(20)			
Alkylphenyl benzene.(20)			
Benzaldehyde.(20)			
2,6-Dinitrotoluene.(20)			
1,2-Diphenylhydrazine.(100)			
Ethyl styrene.(20)			
Methylisopropyl benzene.(20)			
1-Methyl-4(1-methylethenyl)-benzene(20)			20
1-Methyl-4(1-methylethyl)-benzene.(20)			58
Methylpropyl benzene.(20)			
n-Nitrosodimethylamine.(50)			
Chlorinated Aliphatics B/N			
2-Chloroethyl vinyl ether.(20)			
Chlorolmethyl cyclohexadiene.(20)	25	E18	27
1,1-Dichlorobutane.(20)			
Pentachloropropene.(30)			
Non-chlorinated Aliphatics B/N			
Abienol.(50)			
Allocimene.(25)			
Endo-borneol.(50)	E39		140
Bicylohexane.(25)			29
Camphor.(25)	760		38
Delta-3-carene.(25)	E19		
Delta-4-carene.(25)			
Cyclohexenone.(25)	E21	E17	
2-Cyclopenten-1-one, methyl.(25)		42	
p-Cymen-8-ol.(25)	450		600
$C_{20}H_{34}O$ Alcohol.(30)			
Dihydrofuranone.(25)			
Dihydroxycyclohexadiene.(25)	E18		
1,2-Dimethyl cyclohexene.(25)			
Dimethyl cyclopentenone.(25)	130		
2,3-Dimethyl-2-cyclopentenone.(25)	E22		
Dimethyl hexadiene.(25)	E22		
Dimethoxycyclohexadiene.(25)			
Dimethoxycyclohexadiene.#2			
Eugenol.(30)			
Fenchone.(20)			64
Fenchyl alcohol.(25)	140		
Isopropyl substituted alcohol.(25)			
Limonene.(25)			130
4-Methyl-1-(1-methylethyl)-3-cyclohexene-1-ol.(25)	720		
Methoxycyclohexadiene.(20)			
Beta-phellandrene.(20)			
1-Phellandrene	44		20
Alpha-pinene.(20)			

APPENDIX 9 CONTINUED

	19/02/87	24/06/87	02/02/88
Beta-pinene.(20)	74		
Sabinene.(25)			120
Sulphur, S_6.(30)			
Sulphur, S_7.(30)			
Sulphur, S_8.(30)			
Alpha-terpinene.(30)	150		
Alpha-terpineol.(30)	92		
Beta-thujene.(25)	300		
2,3,4-Trimethyl-2-cyclopentene-1-one.(25)		47	110
Trimethyl-2-cyclopentene-1-one.(25)			
PAH's			
1-Methyl naphthalene.(15)			
Phthalate Esters			
Diamyl phthalate.(20)			
Dibutoxyethyl phthalate.(20)			
Dicyclohexyl phthalate.(20)			
Di-(2-ethylhexyl)isophthalate.(20)			
OTHERS			
3,6-Dichloro-2-Methoxybenzoic acid, methyl ester.(25)			
Substituted methyl Ester, MW=176.(25)			
Benzothiazole(20)			
1,2-Benzothiazole.(25)			
2-Chlorobenzothiazole.(25)			
Dichlorodipropyl organic, MW=186.(25)			
2-Chlorodipropyl organic, MW=186.(25)			
Alkylsulfonamide #1 MW=199.(25)			
Alkylsulfonamide #2 MW=199.(25)			
Manool.(100)			
Organic #1, MW>286.(50)			
Organic #2, MW>286.(50)			
Monochloro organic, MW=122.(50)			

Results as µg/L(ppb).
Blank spaces indicate less than the method detection limit.
Method detection limits estimated are given in parenthesis.
E indicates estimated concentration, below instrument integration limit.
NA = not analyzed.

APPENDIX 10. Sampling sites examined for historical water quality data.

REACH	SITE DESCRIPTION	NAQUADAT CODE
u/s Hinton	at Entrance, Alberta (F)	00AL07AD0007
	at old Entrance town site (comp.)	00AL07AD1000
	at old Entrance town site (R)	00AL07AD1010
	at old Entrance town site (L)	00AL07AD1020
	u/s of pulp mill intake	00AL07AD1070
	above Hinton town site (R) - AOSERP	00AL07AD1075
	0.1 km u/s Hinton pumphouse (L)	00AL07AD1080
	0.1 km u/s Hinton pumphouse (C)	00AL07AD1085
	0.1 km u/s Hinton pumphouse (R)	00AL07AD1090
	2.2 km d/s of Maskuta Cr. (L)	00AL07AD1100
	2.2 km d/s of Maskuta Cr. (R)	00AL07AD1120
u/s Whitecourt	at Whitecourt, Alberta (F)	00AL07AE0001
	1 mile above McLeod - AOSERP	00AL07AE1400
	at Hwy #43 Bridge (L)	00AL07AE1490
	at Hwy #43 Bridge (C)	00AL07AE1495
	at Hwy #43 Bridge (R)	00AL07AE1500
u/s Smith	near Hondo, Alberta (F)	00AL07BD0004
	at Hwy #2 Bridge (C)	00AL07BD1000
	at Hwy #2 Bridge (R)	00AL07BD1020
	at Hwy #2 Bridge (L)	00AL07BD1040
	at Hwy #2 Bridge (L and R comp.)	00AL07BD1050
	d/s of railway bridge	00AL07BD1060
at Athabasca	at Athabasca, Alberta (F)	00AL07BE0001
	u/s Town of Athabasca	00AL07BE2250
	1 km u/s Hwy #813 Bridge (L)	00AL07BE2300
	1 km u/s Hwy #813 Bridge (C)	00AL07BE2320
	1 km u/s Hwy #813 Bridge (R)	00AL07BE2340
u/s Ft. McMurray	100 m u/s Horse River - AOSERP	00AL07CC0500
	100 m u/s Horse River (R)	00AL07CC0550
	100 m u/s Horse River (L)	00AL07CC0600
near Old Fort	9 miles u/s Embarras Portage (F)	00AL07DD0001
	at Embarras Airport - AOSERP	00AL07DD0650
	at Embarras Airport (L and R comp.)	00AL07DD0750
	3.5 miles d/s Embarras - AOSERP	00AL07DD0800
	at Old Fort	00AL07DD0900
	u/s Embarras Portage	00AL07DD1000
	at Embarras River - AOSERP	00AL07DD1200
	Big Point Channel Outlet - AOSERP	00AL07DD1900

R right bank
L left bank
C center of channel
F Environment Canada monitoring site
AOSERP Alberta Oil Sands Environmental Research Project

APPENDIX 11. Quality Assurance Information

11.1 Replicate Samples

During surveys 89-1 and 89-3, three replicate grab samples were obtained from the Athabasca River, upstream of Hinton. The replicates were serial grab samples collected about five minutes apart at the same site. During survey 88-1, three grab samples were obtained from the HCE; the samples were collected at four hour intervals on one day. All replicates were submitted 'blind' to the laboratories and analyzed for most parameters except trace organics. These data are included in Appendices 1 to 5, and the statistics describing their variability are in Table 11-1. Such variability provides an indication of the cumulative 'error' that exists in a water quality measurement, that is, small-scale variation in time and space in the river or effluent, sampling and handling error, and laboratory analytical error.

For replicate samples from the Athabasca River, variability, as measured by the coefficient of variation (CV), was relatively high (>25%) for suspended solids, biochemical oxygen demand, dissolved and particulate organic carbon, oil and grease, tannin and lignin, total coliforms, standard plate count (SPC) for bacteria, and many of the metals. In contrast, for the HCE, the CV exceeded 25% for only ammonium-nitrogen and lead. The difference in variability between river and effluent samples was due to the low concentrations of the constituents in the river relative to the HCE. A small absolute

TABLE 11-1. Variability of Replicate Grab Samples

Parameter	HCE Survey 88-1 $\bar{x}$	HCE Survey 88-1 $\underline{s}$	HCE Survey 88-1 CV	ATHABASCA RIVER U/S HINTON Survey 89-1 $\bar{x}$	Survey 89-1 $\underline{s}$	Survey 89-1 CV	Survey 89-3 $\bar{x}$	Survey 89-3 $\underline{s}$	Survey 89-3 CV
DO	6.3	0.15	2	11.7	0.08	1	11.1	0.05	0
TDS				236	3	1	243	0.6	0
Ca	148	2	1	55.3	0.6	1	55.0	0	0
Mg	17.9	0.3	1	17.0	0	0	19.0	0	0
Na	293	5	2	2.7	0.6	22	2.0	0	0
K	8.1	0.06	1	0.5	0	0	0.5	0	0
HCO_3	155	4.6	3	152	0.6	0	151	0.6	0
Cl	566	8.9	2	0.9	0	0	1	0	0
SO_4	196	3.1	2	84.3	1.5	2	91.3	0.6	1
F	0.21	0.012	5	0.14	0.006	4	0.14	0	0
Silica	9.4	0.26	3	4.5	0.06	1	4.3	0	0
SS	59	13.2	22	3	1	33	16	2	13
Turbidity	59	3.6	6	1.9	0.17	9	4.7	0.7	14
Colour	2500	0	0	1	0	0	1	0	0
BOD_5	55.2	2.9	5	0.8	0.69	86	1.0	0.46	46
COD	44.6	4.3	10	4	2	50	<4	0	0
DOC	118	7.6	7	0.4	0	0	0.6	0.44	73
TOC	145	2.6	2						
PC				0.33	0.05	16	1.28	0.46	36
O&G	<1	0	0	0.13	0.06	43	0.2	0.1	50
Phenols	0.11	0.003	3	<0.001	0	0			
T&L	57.4	4.6	8	0.16	0.015	9	0.06	0.017	29
NO_2NO_3-N	<0.003	0	0	0.11	0.005	5	0.1	0	0
NH_3-N	3.19	1.42	45	0.02	0	0	0.02	0	0
TKN	7.24	0.14	2	0.11	0.02	22	0.2	0	0
TDP	0.17	0.03	19						
TP	0.74	0.15	20						
Al (Diss.)				0.02	0.009	46	0.030	0.0057	20
AS				0.0003	0.00005	16	0.0004	0.00005	12
Ba				0.062	0.002	3	0.057	0.0005	1
Be (Diss.)				<0.001	0	0	<0.001	0	0
Cd	<0.001	0	0	0.0016	0.0005	35	0.0013	0.0005	43
Co				<.001	0	0	0.0013	0.0005	43
Cr				0.002	0	0	0.0033	0.0005	17
Cu							0.002	0.001	50
Fe	0.50	0.0057	1	0.078	0.013	16	0.39	0.07	18
Hg(mg/L)	<.05	0	0	<0.1	0	0	<0.1	0	0
Mn				0.0043	0.0005	13	0.014	0.0026	19
Mo				0.0013	0.0005	43	0.0013	0.0005	43
Ni				0.003	0	0	0.0036	0.0005	16
Pb(Extr.)	0.0076	0.0037	49						
Se	<0.0002	0	0				<0.0001	0	0
V				0.0023	0.0005	25	0.0036	0.0005	16
Zn				<0.001	0	0	0.004	0.0026	66
Fecal Col.				<1	0	0	<1	0	0
Total Col.				35	23	66	8	5.3	66
SPC				117	29	24	367	306	83

Concentrations in mg/L, unless noted.
Data are in Appendices 1 to 5.
Metals as totals unless noted.
$\bar{x}$ mean; $\underline{s}$ standard deviation, CV coefficient of variation (%), n=3.

difference in concentration between replicates had a greater effect on the CV for constituents in the river than in the HCE.

11.2 Field Blank Samples

Field blank samples were submitted blind to the laboratories; results are compiled in Table 11-2. Field blanks provide a check for contamination during sampling, handling, and laboratory analysis, and for possible systematic bias in the results.

Most constituents were not detected in the blanks. Concentrations of total dissolved solids, phenols, sulphate, true colour, reactive silica, BOD_5, total Kjeldahl nitrogen and potassium were either at or slightly above detection limits in one or more field blank samples. Particulate carbon and iron concentrations were well above detection limits; even so, the concentrations were low relative to those in the river. Oil and grease, copper, zinc, and SPC were measured in the blanks at concentrations similar to those recorded at many sites in the Athabasca River. Thus, at some sites, the observed concentrations in river samples may have been an artifact of sampling and/or laboratory errors. The effect of high blanks on observed concentrations in the river is discussed in the sections that deal with the parameters.

No trace organic compounds were detected in the blank sample analyzed by Enviro-Test Laboratories. However, several trace organics were detected in the blank samples analyzed by AEC (Table 11-2), perhaps reflecting the lower detection limit and more extensive compound identification at AEC. Trace amounts of benzothiazole and trichlorofluoromethane were tentatively identified in one of two blank samples; these compounds were not detected in river samples. Low

TABLE 11-2. Results for field blank samples, 1989.

PARAMETER	DATE (1989)		
	Jan 18	Feb 22	March 16
TDS	7	6	7
K	0.5	<0.1	<0.1
Sulphate	<3	<3	3
Silica	0.2	<0.1	<0.1
Oil and Grease	0.12	0.47	-
Phenols	<0.001	0.001	<0.001
True colour	3	<1	1
Particulate carbon	0.14	0.03	0.07
BOD_5	0.4	0.4	-
Total Kjeldahl nitrogen	0.06	0.02	-
Cu	<0.001	0.001	0.004
Zn	<0.001	0.004	<0.001
Fe	<0.001	0.009	0.011
Standard Plate Count	1700	<1	-
TRACE ORGANICS	**Feb 6**	**Feb 22**	
Benzoic acid	0.X	2.U	
Hexadecanoic acid	1.X	3.U	
Dibutylphthalate	3.	1.U	
Bix (2-ethylhexyl) phthalate	1.	2.	
Benzothiazole	0.X	1.U	
Chloroform	0.X	2.	
Methylene chloride	21.B	643.B	
Trichlorofluoromethane	0.X	1.U	

Results as mg/L, except true colour (relative units) and trace organics (µg/L). Only detected compounds are listed.

- \- not measured
- X estimated value
- B contamination
- U compound analyzed but not detected, the number is the minimum attainable detection limit for that sample.

All analyzed by AEC, except BOD, bacteria, nitrogen fractions, and DTPA/EDTA by Chemex.

concentrations ($\leq$3µg/L) of benzoic acid, hexadecanoic acid, dibutylphthalate, and chloroform were detected in one of the two blanks. Bis (2-ethylhexyl) phthalate and methylene chloride were detected in both blanks. Phthalate compounds and methylene chloride are often detected in blanks and surface water samples (D. Smillie, pers. comm., Turner 1989, EQMB, unpublished data). They may result from contamination during sampling or analysis, since phthalates occur in plastics, which are common in field and lab equipment (Verschueren, 1983). Methylene chloride is a very common lab reagent and contaminates blanks in many labs (D. Smillie, pers. comm., Turner 1989). Some methylene chloride contamination also resulted from the use of inappropriate collecting vessels in the field, but the problem was corrected and the contaminated results discarded. Because of problems with sample contamination of phthalates and methyl chloride, detection of these compounds was considered false positive; these compounds were excluded from the data set.

11.3 Dissolved Oxygen

Because of the importance of dissolved oxygen (DO) concentrations in the Athabasca River, the primary method of analysis was the azide-Winkler technique. During 1989, dissolved oxygen was also measured at most sites with a Hydrolab Corp., model 4041 meter. Paired DO values measured by the Winkler method and the DO meter for selected groups of sites are listed in Table 11-3. For eight of nine groups, there were no significant differences between the two methods ($P > 0.05$). For the one site where there was a significant difference, DO concentrations measured by the Winkler method were 2.1% greater than by

TABLE 11-3. Paired meter and Winkler dissolved oxygen measurements.

Survey	Headwaters			d/s Hinton			d/s Whitecourt			d/s Suncor		
	H	W	H/W	H	W	H/W	H	W	H/W	H	W	H/W
	mg/L		%	mg/L		%	mg/L		%	mg/L		%
89-1	12	11.65	103.0	11.6	11.45	101.3	9.6	10.03	95.7	12.2	11.89	102.6
	13	12.36	105.2	11.5	11.20	102.7	9.5	8.91	106.7	11.8	11.85	99.6
	9	8.61	104.5	11.7	11.39	102.7	9	8.76	102.7	11.6	11.50	100.9
	5.3	5.28	100.4	11.6	11.05	105.0	8.5	8.6	98.9	10.7	10.35	103.4
	13.4	13.10	102.3	11.3	10.97	103.0	7.6	7.65	99.4	10.7	10.04	106.6
	mean		103.1			102.9			100.7			102.6
	t		3.43			5.12			0.29			1.13
89-2							10.5	9.06	115.9			
							10.4	8.88	117.2			
							9.3	8.37	111.1			
							8.7	7.82	111.3			
							8	7.94	100.8			
	mean								111.3			
	t								3.70			
89-3	12.8	12.84	99.7	11.2	11.4	98.2	9.4	9.32	100.9	11.8	12.09	97.6
	9.4	9.61	97.9	11	11.27	97.6	8.7	8.87	98.1	11.5	11.57	99.4
	5.4	5.95	90.8	10.9	11.08	98.4	7.9	8.57	92.2	10.8	10.80	100.0
	13.5	13.02	103.7	10.5	10.72	98.0	7.5	7.33	102.3	10.7	9.90	108.0
				10	10.28	97.3	7	6.93	101.0	9.7	9.74	99.6
										9.7	9.98	97.2
	mean		98.0			97.9			98.9			100.3
	t		-0.37			-11.8*			-0.68			0.12

H - Hydrolab meter; W - Winkler method, mean of three replicates.
Headwaters - AR u/s Hinton, Oldman Creek, Berland, McLeod and Lesser Slave rivers.
d/s Hinton - AR 1-36 km d/s HCE.
d/s Whitecourt - AR 3km d/s McLeod R. to Ft. Assiniboine.
d/s Suncor - AR d/s Suncor to Lake Athabasca.
* $P < 0.01$, otherwise $P > 0.05$; critical value of t was based on Sidaks multiplicative inequality for k=9, alpha = 0.05.

the Hydrolab DO meter. This difference is small and was likely due to a systematic calibration error in the meter.

11.4 Phenolics

In 1988, samples from the upper Athabasca River system were analyzed for phenolic compounds by Chemex Labs; samples from the lower Athabasca River system were analyzed by AEC. In 1989, all samples were analyzed by AEC. Both labs used NAQUADAT method 06537L on field preserved samples (Appendix 7). There was a discrepancy in results between the two labs for paired grab samples from the Athabasca River; Chemex tended to report lower values and AEC higher values. The two labs have investigated the discrepancy but have not yet resolved it. Phenolic concentrations in three blind field blanks submitted to AEC in 1989 were measured as <0.001, 0.001, and <0.001 mg/L (Table 11-2), which indicates there was no serious contamination or systematic bias in 1989.

11.5 Trace Organic Compounds

In 1988, all river and effluent samples were analyzed for trace organic compounds by AEC. In 1989, river samples were analyzed by AEC; effluents and two river samples were analyzed by Enviro-Test Laboratories. Field blank samples were submitted to both labs; those results are discussed in Appendix 11.2. For the paired river samples from 1989, no priority pollutants were detected by either lab (Table 11-4). However, there were differences between the two labs in the characterization of 'tentatively-identified' compounds. For a sample collected 21 km downstream of the HCE, 12 compounds were tentatively identified by AEC, and only three by ETL (Table 11-4). The discrepancy between the two labs may have resulted from problems with compound characterization by ETL (Erickson, 1989).

TABLE 11-4. Trace organic concentrations at two sites in the Athabasca River, as measured by AEL and ETL, Survey 89-3.

COMPOUND	AR 21km d/s Hinton		AR at Blue Ridge	
	AEC	ETL	AEC	ETL
Extractable Priority Pollutants				
2-Chlorophenol	2.U	1.U	2.U	1.U
2,4-Dichlorophenol	1.U	1.U	1.U	1.U
2,4-Dimethylphenol	2.U	1.U	2.U	1.U
2.4-Dinitrophenol	1.U	5.U	1.U	5.U
2-Nitrophenol	1.U	10.U	1.U	10.U
4-Nitrophenol	1.U	10.U	1.U	10.U
Pentachlorophenol	1.U	5.U	1.U	5.U
Phenol	1.U	5.U	1.U	5.U
2.4.6-Trichlorophenol	1.U	5.U	1.U	5.U
Benzene	1.U	5.U	1.U	5.U
Bromodichloromethane	1.U	10.U	1.U	10.U
Bromoform	5.U	10.U	5.U	10.U
Carbontetrachloride	1.U	5.U	1.U	5.U
Chlorobenzene	1.U	5.U	1.U	5.U
Chloroform	1.B	5.U	1.X	5.U
Dibromochloromethane	1.U	10.U	1.U	10.U
1,2-Dichlorobenzene	1.U	5.U	1.U	5.U
1,3-Dichlorobenzene	1.U	5.U	1.U	5.U
1,4-Dichlorobenzene	1.U	5.U	1.U	5.U
1,1-Dichloroethane	1.U	5.U	1.U	5.U
1,2-Dichloroethane	1.U	10.U	1.U	10.U
1,2-Dichloropropane	1.U	5.U	1.U	5.U
Ethylbenzene	1.U	5.U	1.U	5.U
Methylene Chloride	276.B	5.U	8.B	5.U
1,1,2,2,-Tetrachloroethane	1.U	10.U	1.U	10.U
Tetrachloroethylene	3.U	5.U	3.U	5.U
Toluene	1.U	5.U	1.U	5.U
1,1,1-Trichloroethane	1.U	5.U	1.U	5.U
1,1,2-Trichloroethane	1.U	10.U	1.U	10.U
Tentatively Identified Compounds				
Dimethyl disulphide	2.X	<10	nd	nd
Dimethyl trisulphide	0.X	10.U	nd	nd
Dimethylcyclohexene	0.X	nd	nd	nd
Acetophenone	0.X	nd	nd	nd
Guaicol	1.X	nd	nd	nd
Trimethylcyclopentenone	0.X	nd	nd	nd
Dichlorodimethyl sulphone	3.X	nd	1.X	nd
Trichloroguiacol	0.X	nd	nd	nd
Tetrachloroguiacol	0.X	nd	nd	nd
Veratrole	0.X	nd	nd	nd
p-Cymen-8-ol	0.X	nd	nd	nd
Chlorobenzoic Acid	0.X	nd	nd	nd
Dichlorodehydroabietic acid	nd	<10	nd	nd

Results are in µg/L
X estimated value (rounded)
B contamination
U compound analyzed but not detected, the number is the minimum detection limit for the sample
nd compounds not detected
AEC Alberta Environmental Centre (Vegreville)
ETL Enviro-Test Laboratories (Edmonton)